PROCEEDINGS

OF THE SECOND MEETING OF THE INDIAN ROADS CONGRESS BANGALORE

January 1936

Vol. II

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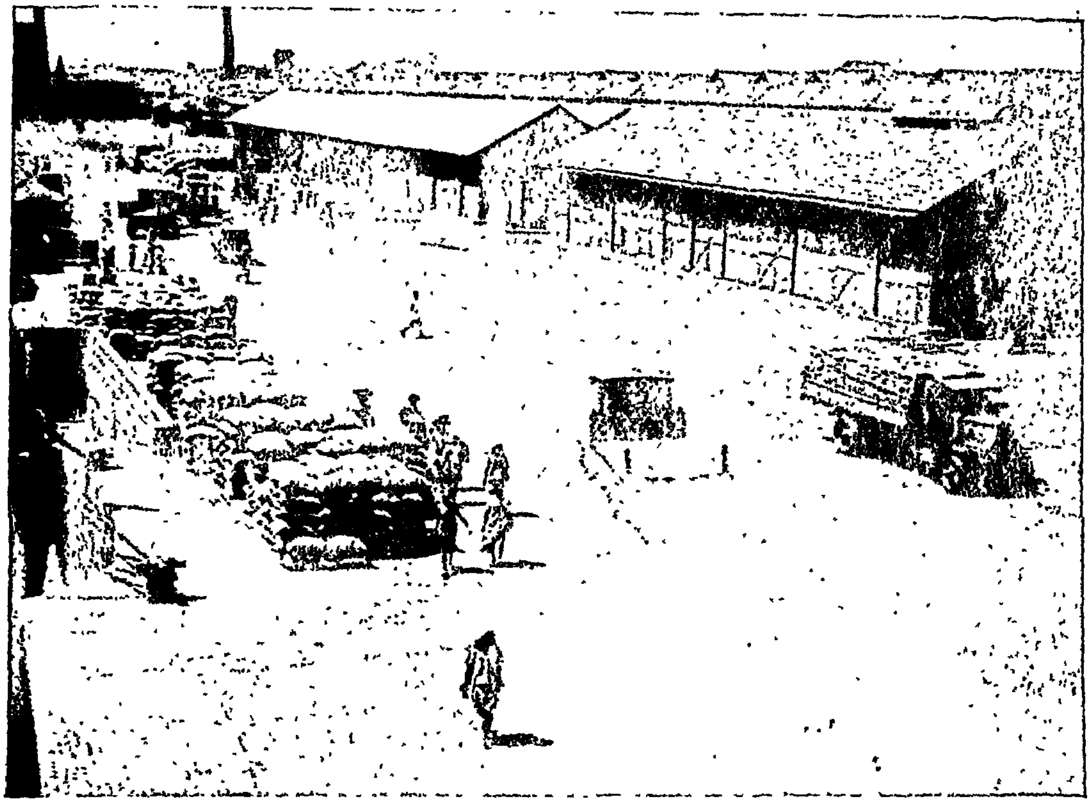

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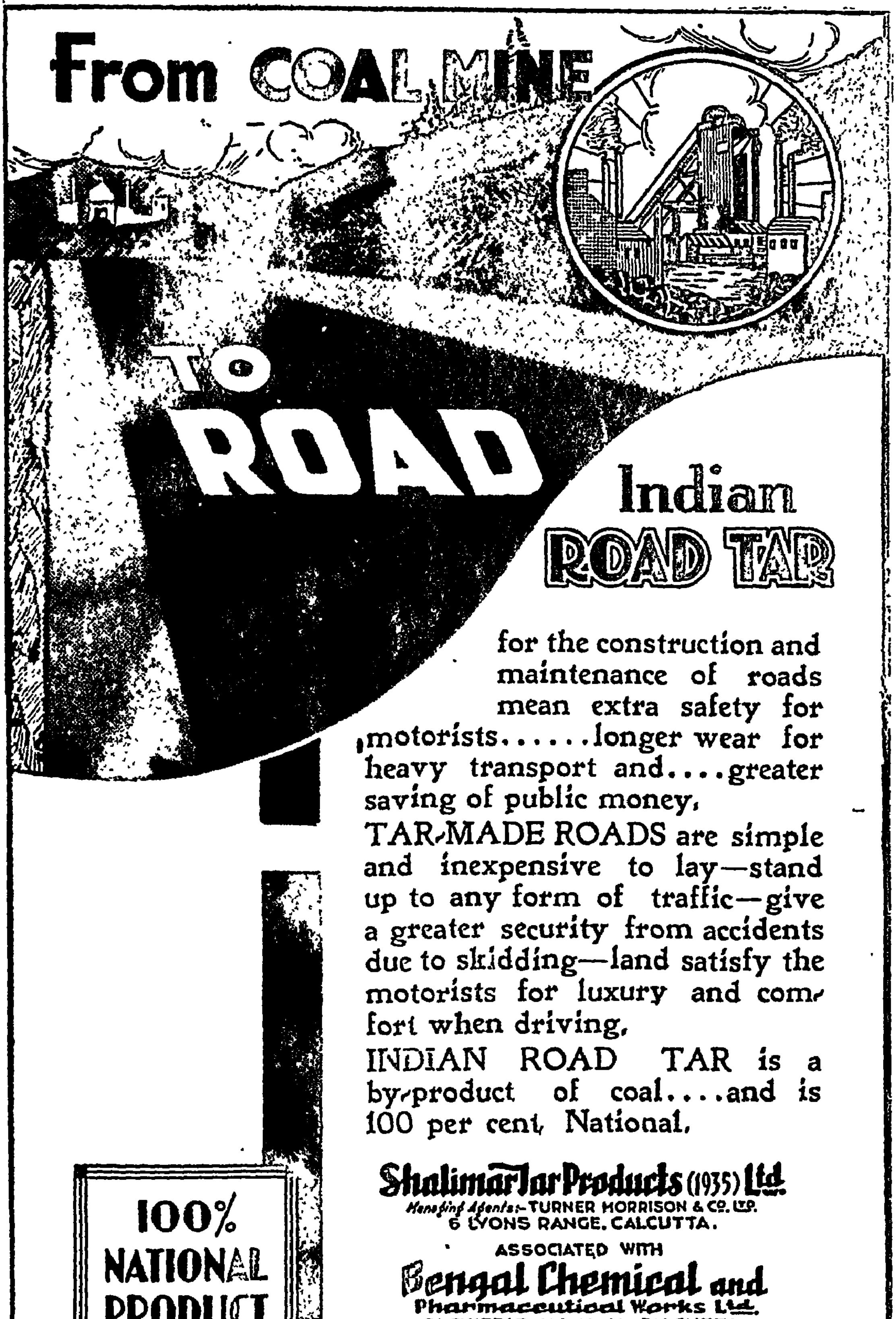
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Proceedings of the Second Meeting of the Indian Roads Congress.

Vol. II **Bangalore** **January 1936.**

CONTENTS.

BUSINESS SESSION.

Proceedings of the Second Meeting of the Indian Roads Congress held at Bangalore on the 9th to 11th January 1936.

The Second Session of the Indian Roads Congress commenced at 10 A.M., on the 9th January 1936, in the Sir Puttana Chetty Town Hall at Bangalore. The following members of the Congress were present:—

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Mr. H. J. Tonks, Offg. Chief Engineer, Rangoon Corporation.

A

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Mr. R. D. Ratnagar. Executive Engineer, Lower Mahanadi Division, Raipur.

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North-West Frontier Province

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Captain W. G. Lang-Anderson, R.E., Superintending Engineer, Peshawar.

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INDIAN STATES.

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Mr. Syed Arifuddin, Superintending Engineer, IV Circle, Hyderabad.

Mysore.

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Mr. R. W. Scaldwell, Superintending Engineer, Mysore.
Mr. H. F. Marker, Superintending Engineer, Shimoga.
Mr. N. Sarabhoja, Superintending Engineer, Irrigation, Mysore.
Mr. M. A. Srinivasachari, Executive Engineer, Bangalore.
Mr. V. V. Patankar, Executive Engineer, Mysore.

MYSORE—*contd.*

Mr. W. H. Murphy, Executive Engineer, Civil and Military Station, Bangalore.

Mr. J. W. Edwin, Assistant Engineer, Civil and Military Station, Bangalore.

Mr. H. Rangachar, Divisional Superintendent, Mysore Railways.

Travancore.

Mr. G. B. E. Truscott, Chief Engineer, Trivandrum.

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Mr. M. R. Patel, Executive Engineer, Navaśari (Baroda State).

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Mr. Taracharan Gue, Chief Engineer, Rewa.

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Mr. K. G. Mitchell, C.I.E., I.S.E., Consulting Engineer to the Government of India (Roads), New Delhi.

Mr. R. L. Sondhi, I.S.E., Assistant to the Consulting Engineer to the Government of India (Roads) and Organising Secretary of the Indian Roads Congress.

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Mr. C. G. Hogg, General Motors, Ltd., Bombay.

A large number of members of the Mysore Engineers Association and of the Mysore Centre of the Institution of Engineers were also present, by invitation.

A number of distinguished guests were also invited to attend the formal opening of the Congress by Amin-ul-mulk Sir M. Mirza Ismail, K.C.I.E., O.B.E., Dewan of Mysore State, and the principal among those who attended were: The Hon'ble Mr. L. G. L. Evans, C.I.E., I.C.S., Resident in Mysore and Mr. S. P. Rajagopalachari, First Member of Council, Mysore Government.

On arrival, the Dewan was received, at the entrance to the Hall, by Rai Bahadur Chhuttan Lal, Diwan Bahadur N. N. Ayyangar, Mr. H. E. Ormerod and Mr. K. G. Mitchell, C.I.E., Members of the Congress Council.

In his inaugural address Sir Mirza spoke as follows:—

MR. CHAIRMAN AND GENTLEMEN,

Your Congress has done a great honour to the State of Mysore in selecting it for the venue of the second of its annual meetings—the meeting which is held to celebrate the close of the first year of its actual existence. In asking me to inaugurate the Congress to-day, you have done me a great honour, for which I thank you.

Roads have become so important in the world of late that it is sometimes hard to recollect that they were once things made to ride upon. Politically, they may help to pacify tribal areas, they may link up great nations, and I hope that soon their influence will begin to be felt through the development of that mutual understanding which is the only true basis for peace. On the other hand, they create new cleavages, dividing the town from the country; setting the owner of the bullock-cart in opposition

to the owner of the car. Economically, they bring the country to the town, the town to the country; they centralise some services; they decentralise others. They bring to market goods that had no chance of reaching it before. They bring children to schools and patients to hospitals who might otherwise never have been able to get there. They are making architects and builders talk seriously about modifications in building design. Financially, they have completely altered our budgets, both public and private. In the days of our grandfathers transport was one of the minor items of the family account. In our days it has become one of the major one. In the case of the public budget the same thing is being felt, and we are groping after a system that will be fair to all parties. This leads to the legislative aspect, in connection with which we see a great deal of legislation all over the world not excepting Mysore. In regard to the æsthetic point of view, Sir Frank Noyce is never tired of telling us that roads and bridges should be things of beauty and joy for ever, while Mr. Punch is never tired of enforcing the same lesson by a converse process, depicting the tragic hiker making his weary way along interminable miles of cement. Roads have their moral aspect too. As all the world knows, evil, communications corrupt good manners, and one has only to read the correspondence columns of the daily press to realise that bad roads make bitter men.

If bad roads make bitter men, good roads do not seem to make polite men. An English friend of mine has something interesting to say on this subject in a letter which I received from him only yesterday. "We had a pleasant time at home," he writes, "bought a new car and toured all over England and a part of Scotland. This is the first time we have had a car at home and we found England a very beautiful country though danger lurks on the roads. Some of the car drivers are wickedly dangerous and the penalties inflicted are far too light. We have always been a law-abiding nation but the coming of the speed car has made us fall a bit in our reputation."

Is it not possible, however, to take the view that the real offender is not so much the motorist as the engineer? For is it not he who either provokes the motorist by his bad roads or tempts him by his magnificent ones? The result is the same in either case—the poor motorist forgets himself and his manners!

While I said that it is a great honour to Mysore that you should make the State the centre of your discussions and inspections, I cannot pretend that we have anything very remarkable in the matter of new extensions or experiments in road-making to demonstrate. Our chief product in this field up to date is the new law that came into force just over a week ago, which we hope will regularise many things that were irregular before, and will produce a fund out of which a steady programme of road development can be undertaken. We have also gone some considerable way in the matter of the bridging of both rivers and railways, and of making by-passes round populous villages. We have not done a great deal in the matter of development of new roads, the total new milage made in the past ten years being 165 as against 3,355 in Britain, where they spend the huge sum of £50,000,000 and more a year on the making and upkeep of roads and on, to them, the still more urgent problem of road safety. Nor have we yet begun to feel the necessity for additional milage in the way in which it is felt in some Western countries, where the week-end holiday-maker is apt to spend his week-end in a queue of cars. This is largely due to the fact that we have not yet had any very great development in motor car traffic, the

total number of people per private car in Mysore being 4,229, as against 32 in England and 6 in the United States, I am thankful to say that we have also the converse of this, and against America's 36,000 deaths from road accidents in 1934, not to speak of the 800,000 and more injured, we have a record of only 19. The figures for Britain are 6,521 killed and 219,000 injured for the same period.

There is, of course, an obvious explanation for this; the roads in India are neither so crowded nor are they anything like those in Europe or America; they offer no such inducements to greater car milage, greater speeds and increasing deaths.

Dr. Miller McClintock, Director of the Bureau for Street Traffic Research at Harvard University, points out that the chief function of the ideal highway is to compensate for the driver's mistakes. "We now have," he says, "vehicles and highways which can be used safely by safe drivers. It is possible, however, so to improve highway construction as to give added protection against the failure of the human factor." He proceeds to describe various types of road conflicts and suggests that it is most important that every highway should have a medial strip—a safety zone separating opposing streams of traffic.

The ideal road is one in which the driver meets nothing unexpected. The building of such roads is more a matter of economics than of road-engineering. We in India have not yet arrived at a stage when it has become a matter of imperative necessity to have such roads—roads having one-way traffic with a safety island separation, proper lighting, long radius of curves, clover-leaves, and over-passes at intersecting roads. What the engineer in India is chiefly engaged in at present is the improvement of the road-surface. This in itself constitutes a problem, having regard to the different kinds of vehicles using our roads and to the paucity of funds provided for the purpose. A writer in a recent issue of the "New York-American" expressed the view that aviation would eventually prove the most economical form of transportation.. Until that time arrives—I suppose it will arrive sooner or later—roads will demand the closest attention of the engineer.

I gather that your Congress very wisely covers only a part of an immense subject. You have an International Roads Congress which deals with problems that are common to several nations or to the whole world, and National Congresses and Highway Research Boards in different countries. Here in India you have the Transport Advisory Council dealing with the major questions of policy, while you yourselves deal with the technical details. In regard to these matters, I see you have on your agenda a host of papers dealing with many aspects of road-making, and I sincerely hope that the result of your deliberations will be to achieve what has hitherto proved impracticable, that is, to devise a road that will be suitable both for the motor car and for the bullock-cart and acceptable to the harassed Finance Member as well as to the ambitious Engineer.

With this hope, Gentlemen, I leave you to your deliberations.

The Congress then adjourned for the Group Photograph which was taken outside the Sir Puttana Chetty Town Hall.

(An account of the inspectional tours to important roadworks, other works and places of interest held in connection with the Second Congress appears as the Appendix to these proceedings.)

First day, Thursday, January 9, 1936.

GROUP 1: TRAFFIC CENSUS AND USE OF RESULTS THEREOF (PAPERS Nos. 14, 15 AND 16).

Chairman: Diwan Bahadur N. N. Ayyangar.

After the Group Photograph was taken, the Congress re-assembled at the Sir Puttana Chetty Town Hall, Bangalore, at 11 A.M.

Chairman: Gentlemen, the first group of papers on traffic census and the use of results thereof, *i.e.*, papers Nos. 14, 15 and 16 will be taken together. The papers having been distributed already, they will be taken as read. They are now open to discussion. Anyone who has to make any remarks may kindly do so. The authors will introduce the papers with any general remarks they might have to make in addition to what is written in the papers.

The following paper was taken as read:—

Paper No. 14.

AN ANALYSIS OF DELHI ROAD TRAFFIC CENSUS.

BY

R. L. Sondhi, I.S.E., Assistant to the Consulting Engineer to the Government of India (Roads).

1. *Preliminary remarks.*—The only object of roads is to serve traffic. Therefore a definite knowledge of the volume and character of the traffic is essential for sound highway planning. This can be obtained by traffic surveys which should be judiciously conducted to get at convincing knowledge of the kind of traffic information needed.

2. The necessity of conducting some sort of traffic census for the purpose of comparing the wear of different types of surfaces is obvious and the Committee of Chief Engineers that sat in 1931 adopted a standard method of recording traffic counts, but till recently the results obtained have been irregular and not susceptible of comparison. In 1934, therefore, it was decided to carry out a full census at various points round Delhi, not only in order to obtain accurate information as to the nature and extent of traffic on various experimental road surfaces, but also to obtain experience of how the thing should be carried out and the results recorded. It had also the possibly "Machiavellian" object of checking the loading of motor vehicles entering Delhi from the United Provinces and the Punjab. These Provinces believed that there was, as a general rule, no overloading and little or no long distance goods lorry traffic. The railways on the other hand alleged considerable overloading and long distance traffic.

3. While therefore the primary motive of a study of road traffic on the approaches to Delhi was to obtain reliable statistics from which to study the economics of certain experimental roads surfaces, the geographical position of Delhi makes it very suitable place at which to make such a more detailed traffic study.

4. *Objects of the Model Survey.*—Briefly stated, therefore, the objects of taking the census were :—

(1) To ascertain the total traffic on various roads approaching Delhi;

(2) To analyse, as far as possible, that traffic and to determine the origin and range of bus, lorry, agricultural cart and hired cart traffic when in competition with railways and to some extent the nature of goods carried;

(3) To ascertain to what extent buses and lorries are in fact overloaded in order to throw some light on this aspect of the road and rail controversy.

5. *Count of Total Traffic.*—In order to be able to get at an accurate volume count of the traffic flowing into and out of Delhi by road, the next important point was a judicious selection of *census points* and the following six counting stations were selected on the main approaches to the City:

(1) G. T. Karnal Road Mile 4/4;
(2) G. T. Meerut Road Mile 3/5;
(3) Delhi-Muttra Road Mile 4/7
(4) Delhi-Rohtak Road Mile 3/4;
(5) Delhi-Gurgaon Road *via* Basant Mile 9/4; and
(6) Delhi-Gurgaon Road *via* Mahrauli Mile 7/8.

These are shown in the map at the end of this paper.

6. *Time for Counting and Duration of Counts.*—The next question was to decide the duration of this survey. It was obvious that the special staff which it was necessary to employ would take some time to train and as men employed for broken periods of a few days could hardly be depended upon to do the work satisfactorily, it was decided to conduct a continuous survey for six months. It was further decided to follow the main survey by test counts at certain periods of the day and the week for the remaining six months in order to arrive at seasonal variations. The continuous count of traffic was commenced on the 1st October 1934 and completed on 8th April 1935 and the present paper deals only with this part of the survey.

7. The actual number of days and the periods during which the count was made at each point are given below :—

(1) G. T. Karnal Road	1st Round		from 1st October 1934 to 10th October 1934.
	2nd "		from 9th December 1934 to 18th December 1934.
	3rd "		from 10th February 1935 to 19th February 1935.
		30 days	
(2) G. T. Meerut Road	1st Round		from 12th October 1934 to 21st October 1934.
	2nd "		from 21st December 1934 to 30th December 1934.
	3rd "		from 20th February 1935 to 1st March 1935.
		30 days.	

(3) Delhi-Muttra Road	1st Round		from 24th October 1934 to 2nd November 1934.
	2nd „		from 2nd January 1935 to 11th January 1935.
	3rd „		from 4th March 1935 to 13th March 1935.
		30 days.	
(4) Delhi-Rohtak Road	1st Round		from 5th November 1934 to 14th November 1934.
	2nd „		from 14th January 1935 to 23rd January 1935.
	3rd „		from 17th March 1935 to 26th March 1935.
		30 days.	
(5) Delhi-Gurgaon Road *via* Basant .	1st Round		from 17th November 1934 to 26th November 1934.
	2nd „		from 26th January 1935 to 4th February 1935.
	3rd „		from 29th March 1935 to 7th April 1935.
		30 days.	
(6) Delhi-Gurgaon Road *via* Mahrauli .	1st Round		from 28th November 1934 to 6th December 1934.
		10 days.	

The total number of days on which counts were made at each of the first five stations was 30; but on the Gurgaon Road *via* Mahrauli a count was made on the first round only for ten days; thus, the number of actual count days was 160 during the six months, the remaining days being taken in the transfer of staff and paraphernalia from one point to another and for breaking the rotation of shifts.

8. It will be seen that a rotational system was adopted by checking on the various traffic points in turn for ten days and then moving the staff on to the next. It was thus possible to count the traffic thrice at intervals of about two months in the case of five out of the six census points.

9. The counting was carried out throughout the 24 hours and this was necessary to get at the truth about the allegation that there was a lot of goods transport at night in motor buses or motor lorries evading such control of overloading, etc., as there may be. This was one of the things we wanted to know and the idea of the survey was to ascertain facts and not to check offences. It was, therefore, broadcast that there was no suggestion of any prosecutions arising out of the investigations; as although launching of such prosecutions would have resulted in temporary improvement in regard to observance of rules it would have disguised facts and suppressed information as to the normal state of affairs. As some difficulty was apprehended in the stopping and weighment of lorries, the co-operation of the Police was obtained; but it must be said to the credit of the lorry-drivers that police assistance was seldom necessary.

10. *Special Census Staff.*—The staff consisted of a head enumerator a Rs. 50 per mensem in general charge and six enumerators and six peons a Rs. 30 and Rs. 15 respectively. The enumerators worked in three eight-hour

shifts throughout the 24 hours, each shift consisting of two enumerators and two peons. The head enumerator generally supervised and consolidated the statistics.

11. *Cost.*—The total cost of this rather detailed census, perhaps the first of its kind in India amounted to about Rs. 5,900, which included a sum of Rs. 2,000 for the purchase of a pair of Avery's portable wheel weighers, called 'Load-O-meters', for testing the loads carried on motor vehicles and bullock carts. This sum was provided from the budget for research and experiment chargeable to the "Reserve" in the "Road Fund".

12. *Count-forms and work in the field.*—Four special forms (reproduced at Appendix I to this paper) were evolved for use in the field, based upon the one approved by the Committee of Chief Engineers referred to earlier in this paper. These were printed on papers and not cards, the enumerators were provided with boards and clips with which to use these.

13. Forms 1 and 2 (see Appendix I) need little explanation and are really tally sheets for vehicular traffic and provided for the segregation of motor and non-motor vehicles and their sub-classification under special weight groups, which was necessary as such a classification has very fundamental bearing on design of road structure. These were filled in by the enumerators on duty for each vehicle that passed the census point and as indicated in the first column time was noted and a line drawn every three hours. This is of considerable importance in determining the fluctuations in volume and character of traffic during the various hours of day and night. This was also necessary for use in comparing "Short-count" traffic Surveys which are to follow.

14. A few typical vehicles were actually weighed and their weights and other particulars mentioned hereinafter were recorded in form No. 3. Very soon the staff, by practice, acquired a mental faculty to make a shrewd guess at weights of vehicles, which on actual weighing were found not to be far out. Moreover quite a number of vehicles running up and down the same route were passing the respective census point again and again, it was not necessary to hold these up to note the weights and other particulars. An aid in guessing the load or over-load on motor vehicles is the degree to which the springs are depressed.

15. Full particulars of motor vehicles were taken. If the registration certificate specified load in passengers or goods or laden weight this was noted. Also in order that ultimately over-loading weight also be checked from the makers' specifications, the make of the motor vehicle and the chassis number were recorded. Particulars of the origin, destination and contents of vehicles were taken while they were being weighed. If these particulars were taken for more vehicles than were weighed, the same form was used and the particulars of weight were left blank. A summary was prepared by the head enumerator on form No. 4 for each 24 hours count.

16. Temporary wooden barriers for blocking the traffic for the purposes indicated above were made; but it must be said to the credit of the traffic that their use was not found essential, as drivers co-operated in the collection of the information and stopped or went slow as required. As remarked above this was probably due to their being free from the fear of prosecutions for carrying overloads. Red flags during day and red-lights during night were used as signals for stopping traffic and a notice board on the side of the road near the census-point indicated that the census was being conducted under authority.

16. *Traffic data collected.*—In order to accomplish the objects aimed at the following information was obtained :—

I. *Motor traffic.*—Total traffic in each direction by numbers of—
(a) Private motor vehicles including taxis ;
(b) Motor buses ;
(c) Motor lorries ; and
(d) Motor buses working as lorries, *i.e.*, carrying goods only.

II. In the case of motor buses only—
(a) number of passengers ;
(b) seating capacity for which licensed ;
(c) loaded weight and
(d) length of trip.

III. In the case of motor buses acting as lorries and of lorries carrying goods or empty—
(a) actual weight carried ;
(b) weight for which registered ;
(c) class of goods ;
(d) length of trip and
(e) extraordinarily long trips, *e.g.*, fruit from Kashmir.

IV. In the case of agriculturists' bullock carts :—
(a) distance travelled ;
(b) load ;
(c) proportion with iron tyres : and
(d) width of tyres.

V. In the case of non-agriculturists' bullock-carts for 4-wheeled carts and 2-wheeled carts separately :—
(a) distance travelled ;
(b) load ;
(c) class of goods ;
(d) proportion with iron tyres, which is more or less 100 per cent. and
(e) width of tyres.

17. *Collateral Studies.*—While the counts were being made it was considered desirable to obtain other information that might be required subsequently. Opportunity was taken to study the actual destructive effect and the pressure intensities which the different types of vehicles, particularly bullock-carts, exercise on roads. This necessitated the determination of the actual bearing surface of tyres. To find these accurately impressions of cart-tyres were taken on paper by interposing carbon paper and it was found that the width of actual contact was much less than is usually supposed. On the stone setts and cement-concrete surfaces the area of contact appears to be so reduced that the intensity of pressure is over 4,000 pounds per square inch ! A more detailed account of these studies is the subject of a separate paper to be introduced at this Congress by Messrs. Sinha and Abbasi of the Central Public Works Department.

18. *Form of presentation of traffic data.*—A preliminary study has been made of the results obtained and a set of statements has been prepared (*vide* Appendix II). In presenting statistics of this sort it is desirable to avoid overloading individual statements or to attempt to show too much at a time. It is better to repeat the figures on separate statements than to overload one. It is best to start with a condensed abstract and then elaborate in other statements.

19. *Practical application of the compiled data.*—Although the results are being further studied and analysed it will be of interest to comment on the practical utility of the information presented in each of the statements compiled so far (*vide* Appendix II) :—

20. *Statement No. 1* shows the average daily traffic volume of all vehicles, motor and non-motor. The traffic per yard width of metalled surface is stated because this figure is still of interest to some people; but this appears to be of little practical value because there are three very serious variables in borms, type of traffic and width of surfaced portion. It has been recommended by the Technical Sub-Committee of the Congress that the figure to be recorded is the absolute or total tons per 24 hours in both directions for metalled surfaces upto 20 feet wide. This important information is exhibited in this statement, which also shows at a glance the high proportion, 70 per cent. of animal-drawn vehicular traffic.

21. *Statement No. 2.*—The object is to analyse motor traffic and to obtain some idea as to the relative tonnage of private cars, buses and lorries. It shows that light private cars constitute about 35 per cent., medium weight passenger buses 41 per cent. and heavy lorries carrying goods about 24 per cent. of the total motor-traffic. As no regular long-distance taxi-services exist, the first type of traffic mainly consists of ordinary business intercourse and short pleasure trips. The very large lorry traffic on the Delhi-Muttra road is due almost entirely to traffic from brick kilns in which, at the time of the census, motor lorries had largely replaced bullock-carts. It will, however, be seen from statement No. 5 that these were very greatly overloaded and it will be interesting to see, from later investigations, whether this use of lorries continues despite the overloading which would appear to be so gross as to be destructive of the vehicles and to render the use of the lorries for this purpose uneconomical.

22. *Statement No. 3.* is an analysis of the motor bus traffic and is intended to show the extent of overloading as regards the number of passengers; and the range travelled. It is interesting to note that, on the average, buses when they reached the census point were not overloaded. It is also remarkable that on the approaches to Delhi a very large proportion of buses are working on a route of less than 50 miles. It is not impossible, however, that these figures may be faulty and they constitute one of the features of the census which requires further investigation and check; because it is natural for a driver, when asked where he comes from, to mention the last big town on the route instead of the place from which he actually started in the morning. For further accurate origin and destination studies, therefore, the 'interview method' so far used may have to be supplemented by some sort of 'Card-reply method', in which these entries may have to be certified by the road or traffic authorities at both ends of the journey.

23. *Statement No. 4* is a similar analysis in the case of motor lorries carrying goods and here it will be seen that the number using a route above 50 miles is not very great, but is greatest on the G. T. Karnal Road down which come consignments of fruit from the Punjab and beyond.

24. *Statement No. 5* is an analysis of the range and overloading of lorries. As regards the extent of overloading it will be observed that it is as great on long distance routes as on short ones.

25. *Statement No. 6* merely shows what proportion of the lorries on the road are overloaded to a greater or less extent. It will be seen that practically cent. per cent. of the lorries running on long distance routes are overloaded, which is not the case with short distance travel where the percentage varies from 4 to 50 only for the various census points.

26. *Statement No. 7* again refers to overloading and distinguishes between the excess 'gross load' and excess 'pay load', the former being expressed as 'excess weight per cent.' and the latter as 'excess load per cent.'. Here it is interesting to see that, while the actual excess gross weight varies from 24 to 74 per cent. of the 'registered laden weight', the actual 'pay load' carried may sometimes be nearly three times that for which the vehicle is registered and presumably designed. The main trouble so far as overloading is concerned is the fact that a vehicle built for a ton and half frequently carries three and even over four tons, and it cannot be expected that the brakes are capable of ensuring safety. In order to save the roads from excessive wear and tear the introduction and strict enforcement of more rigid motor vehicle rules is indicated.

27. *Statement No. 8* is merely an analysis of bullock cart traffic into purely agricultural and professional carting. This is of interest because if the use of pneumatic tyred bullock carts is likely to develop at all it will be first and for a long time only in the professional cartmen's class. This statement therefore gives, for the particular census points, some idea as to the proportion of the destructive bullock cart traffic which would be affected by the introduction of pneumatic tyred carts.

28. *Statement No. 9* gives an analysis of bullock cart traffic showing the range as far as could be ascertained by enquiry from the drivers. The object of this analysis was to obtain some idea as to the extent to which bullock carts can compete with railways and motor lorries in the carriage of goods. It will be seen from the map, at the end of this paper, that for about fifty miles round Delhi the roads on which the census points lie, are, with the exception of the Delhi-Gurgaon road closely parallel with railways and even the Delhi-Gurgaon road approaches close to the railway at Gurgaon about twenty miles out. Carts having a range over 25 miles may be said to be in competition with railways and from this statement it will be seen that their daily average number varies, for the various census points, from 1 to 50, the latter number being in the case of G. T. Meerut Road, which is chiefly accounted for by the transport of grain from Ghaziabad side.

29. *Statement No. 10* is an analysis of bullock carts into two-wheeled and four-wheeled and in the case of two-wheeled agriculturists' carts shows the average number which have iron tyres. As practically all non-agriculturists' carts are fitted with iron tyres that analysis is not made in that case. It will be seen that the majority of agriculturists' carts do not have iron tyres but travel on the wooden felloe which is not nearly so destructive and is usually reasonably smooth. Taken with statement No. 8 this statement shows that for the census points dealt with the replacement of non-agriculturists' bullock carts by rubber-tyred carts or by motor lorries would very substantially reduce the number of destructive bullock carts using the roads.

30. *Conclusion.*—The studies so far made relate to information that was gathered at the six count stations. It is intended to continue the examination of the present data with the hope of arriving at further useful information. With the help of subsidiary traffic counts, where necessary conducted on the 'short count method', on different points on the same road, including the Delhi Province boundary and other intervening places where cross roads from important towns and villages join, it should be possible to obtain comparative densities and to prepare a 'traffic-flow' map for the trunk-road system of the Province. Such a map with the help of repeated, if possible annual, censuses will serve an important purpose in interpreting traffic distribution, volume and character, which will make it possible for the road authority to design the improvements so that these will accurately fit the kind of traffic to be carried. It is hoped that further examination of the figures and subsidiary counts may provide material for a further paper on this subject.

APPENDIX I.

FORM No. I.

MOTOR TRAFFIC.

Traffic count at——————————on—————— ————Road.

From————————hours on——————to———— ———hours on————.

Recorded by————————————————————————.

Lorries, and Buses over 25 seats.		Buses up to 25 seats.	Cars and Taxis.	Miscellaneous.
Solid tyres.	Pneumatic tyres.			

NOTE.—If desirable to obtain particulars of diurnal fluctuations, the time may be noted here every 3 hour and a line ruled across.

FORM No. 2.

NON-MOTOR TRAFFIC.

Traffic count at——————on——————Road.

From————hours on————to————hours on————.

Recorded by————————————.

4-wheeled carts.		2-wheeled carts.				Passenger vehicles.	
		1 animal.		2 or more animals.			
Loaded.	Empty.	Loaded.	Empty.	Loaded.	Empty.	1 animal.	2 or more animals.

NOTE.—If desirable to obtain particulars of diurnal fluctuations, the time may be noted here every 3 hour and a line ruled across.

FORM No. 3.

WEIGHMENT SHEET.

Date and Time.	Vehicle weighed. Make, registered No. and chassis No. in case of Motor, Bus or Lorry, also origin, destination and contents of vehicles weighed.	Sum of weights of		
		Front wheels.	Back wheels.	Total.

FORM No. 4

SUMMARY SHEET.

Traffic count at———————————on——————————Road.

Nature of road surface ————————————————————.

Width of road surface——————feet——————yards——————.

Width of formation——————feet——————.

During 24 hours ending.	Attached Sheet No.	Total weight in tons.			Weight in tons per yard width of hard surface.		
		Motor.	Other.	Total.	Motor.	Other.	Total.

APPENDIX II.

STATEMENT No. 1.

Statistics regarding average total traffic for 24-hours for six months from 1st October, 1934 to 8th April, 1935.

Census Point.	Width of metalled surface. (in feet.)	Motor Transport. No. of vehicles.	Motor Transport. Total weight. (in tons.)	Non-motor transport. No. of vehicles.	Non-motor transport. Total weight. (in tons.)	All Vehicles. No. of vehicles.	All Vehicles. Total weight. (in tons.)	Weight per yard width of metalled surfaces per 24 hours. (in tons.)
G. T. Karnal Road, Mile 4/4	12	86	213·7	319	354·1	405	567·8	142·0
G. T. Meerut Road, Mile 3/5	24	268	697·1	441	585·4	709	1282·5	160·3
Delhi-Muttra Road, Mile 4/7	18	258	776·4	385	519·5	643	1295·9	216·0
Delhi-Rohtak Road, Mile 3/4	12	124	381·2	444	391·7	568	772·9	193·2
Delhi-Gurgaon Road, *via* Basant, Mile 9/4	12	113	312·9	107	160·3	220	473·2	118·3
Delhi-Gurgaon Road, *via* Mahrauli, Mile 7/8	24	97	165·1	333	590	430	755·1	94·4

STATEMENT No. 2.

Statistics regarding average motor traffic per 24-hours for six months from 1st October, 1934 to 8th April, 1935.

Census Point.	Private cars and taxis.			Buses.			Lorries.			Total weight per 24 hours, all motor vehicles. (in tons).
	Number.	Weight assumed per vehicle. (in tons).	Total weight. (in tons).	Number.	Average ascertain-ed weight. (in tons).	Total weight. (in tons).	Number.	Average ascertain-ed weight. (in tons).	Total weight. (in tons).	
G. T. Karnal Road, Mile 4/4.	31	1·2	37·2	40	2·9	116·0	15	4·0	60·0	213·2
G. T. Meerut Road, Mile 3/5.	95	1·3	123·5	140	3·1	434·0	33	4·2	138·6	696·1
Delhi-Muttra Road, Mile 4/7.	72	1·4	100·8	55	3·3	181·5	131	3·8	497·8	780·1
Delhi-Rohtak Road, Mile 3/4.	23	1·5	34·5	88	3·5	308·0	13	3·2	41·6	384·1
Delhi-Gurgaon Road, *via* Basant, Mile 9/4.	36	1·4	50·4	48	3·3	158·4	29	3·7	107·3	316·1
Delhi-Gurgaon Road, *via* Mahrauli, Mile 7/8.	72	1·1	79·2	18	3·2	57·6	7	4·3	30·1	166·9

Statement No. 3.

Statistics regarding total average motor bus traffic per 24-hours for six months from 1st October, 1934 to 8th April, 1935.

Census Point.	Total number of buses per 24-hours.	Average licensed seating capacity.	Average number of passengers carried.	Number of buses travelling on route of length.		
				0—50 Miles.	50—100 Miles.	Over 100 Miles.
G. T. Karnal Road, Mile 4/4.	40	21	17	26	12	2
G. T. Meerut Road, Mile 3/5.	140	21	20	135	3	2
Delhi-Muttra Road, Mile 4/7.	55	21	19	44	6	5
Delhi-Rohtak Road, Mile 3/4.	88	21	21	63	15	10
Delhi-Gurgaon Road, *via* Basant, Mile 9/4.	48	21	21	46	1	1
Delhi-Gurgaon Road, *via* Mahrauli, Mile 7/8.	18	21	18	17	..	1

Statement No. 4.

Statistics regarding total average motor lorry traffic per 24-hours for six months from 1st October, 1934 to 8th April, 1935.

Census Point.	Number of lorries per 24-hours on routes of length.			Total number of lorries per 24-hours.
	0—50 Miles.	50—100 Miles.	Over 100 Miles.	
G. T. Karnal Road, Mile 4/4 .	6	4	5	15
G. T. Meerut Road, Mile 3/5 .	30	1	2	33
Delhi-Muttra Road, Mile 4/7 .	127	3	1	131
Delhi-Rohtak Road, Mile 3/4 .	11	1	1	13
Delhi-Gurgaon Road, *via* Basant, Mile 9/4.	28	..	1	29
Delhi-Gurgaon Road, *via* Mahrauli, Mile 7/8.	7	..	..	7

STATEMENT No. 5.

Statistics regarding average daily number of overloaded lorries per 24-hours for six months from 1st October, 1934 to 8th April, 1935.

Census Point.	0—50 Miles Range.			50—100 Miles Range.			Over 100 Miles Range.			Total number of overloaded lorries per 24-hours.
	No. of Vehicles overloaded.	Average R. L. W., per vehicle. (in tons.)	Average gross actual weight per vehicle. (in tons.)	No. of Vehicles overloaded.	Average R. L. W., per vehicle. (in tons.)	Average gross actual weight per vehicle. (in tons.)	No. of Vehicles overloaded.	Average R. L. W., per vehicle. (in tons.)	Average gross actual weight per vehicle. (in tons.)	
G. T. Karnal Road, Mile 4/4.	3	3·6	5·9	2	4·5	5·9	5	2·5	3·6	10
G. T. Meerut Road, Mile 3/5.	12	3·6	6·4	1	3·6	5·5	2	3·6	5·5	15
Delhi-Muttra Road, Mile 4/7.	54	3·6	6·1	..	..	..	..	..	..	54
Delhi-Rohtak Road, Mile 3/4.	5	3·6	5·3	1	3·6	5·4	1	3·6	5·4	7
Delhi-Gurgaon Road, *via* Basant, Mile 9/4.	1	3·6	4·5	..	..	..	1	3·6	4·5	2
Delhi-Gurgaon Road, *via* Mahrauli, Mile 7/8.	2	3·6	5·5	..	..	..	..	..	..	..

STATEMENT No. 6.

Statistics regarding average percentage of overloaded lorries per 24-hours for six months from 1st October, 1934 to 8th April, 1935.

Census Point.	0—50 Miles Range.			50—100 Miles Range.			Over 100 Miles Range.			Average percentage of over loaded lorries.
	Total No. of lorries.	Total No. of over-loaded lorries.	Percentage of over-loaded lorries.	Total No. of lorries.	Total No. of over-loaded lorries.	Percentage of over-loaded lorries.	Total No. of lorries.	Total No. of over-loaded lorries.	Percentage of over-loaded lorries.	
G. T. Karnal Road, Mile 4/4 . .	6	3	50	4	2	50	5	5	100	
G. T. Meerut Road, Mile 3/5 . .	30	12	40	1	1	100	2	2	100	
Delhi-Muttra Road, Mile 4/7 . .	127	54	43	3	..	..	1	..	..	
Delhi-Rohtak Road, Mile 3/4 . .	11	5	45	1	1	100	1	1	100	
Delhi-Gurgaon Road, *via* Basant, Mile 9/4 . . .	28	1	4	..	..	..	1	1	100	
Delhi-Gurgaon Road, *via* Mahrauli, Mile 7/8 . . .	7	2	29	..	..	..	..	..	..	

STATEMENT No. 7.

Statistics regarding overloaded lorries showing (1) Average "excess weight per cent.", (2) Average "excess load per cent." per 24-hours from 1st October, 1934 to 8th April, 1935.

Census Point.	Average ascertained gross weight per lorry. (in tons.)	Average R. L. W., per lorry. (in tons.)	Average excess weight per lorry. (in tons.)	Average unladen weight per lorry. (in tons.)	Average legal load per lorry. (in tons.)	Average excess load per lorry. (in tons.)	Average excess weight per cent.	Average excess load per cent.
G. T. Karnal Road, Mile 4/4	4·7	3·6	1·1	2·1	1·5	1·1	31	75
G. T. Meerut Road, Mile 3/5	6·2	3·6	2·6	2·1	1·5	2·6	72	173
Delhi-Muttra Road, Mile 4/7	6·1	3·6	2·5	2·1	1·5	2·5	69	165
Delhi-Rohtak Road, Mile 3/5	5·3	3·6	1·7	2·1	1·5	1·7	48	116
Delhi-Gurgaon Road, *via* Basant, Mile 9/4	4·5	3·6	·9	2·1	1·5	·9	24	58
Delhi-Gurgaon Road, *via* Mahrauli, Mile 7/8	5·5	3·6	1·9	2·1	1·5	1·9	51	123

Statement No. 8.

Statistics regarding average total bullock-cart traffic per 24-hours for six months from 1st October, 1934 to 8th April, 1935.

Census point.	Agriculturists bullock-carts.			Non-agriculturists bullock-carts.			Total average weight per 24-hours for all bullock-carts. (in tons.)
	Number.	Weight ascertained per vehicle. (in tons.)	Total weight. (in tons.)	Number.	Weight ascertained per vehicle. (in tons.)	Total weight. (in tons.)	
G. T. Karnal Road, Mile 4/4 . . .	111	1·5	166·5	67	1·7	113·9	280·4
G. T. Meerut Road, Mile 3/5 . . .	115	1·1	126·5	220	1·5	330·0	456·5
Delhi-Muttra Road, Mile 4/7 . . .	150	1·4	210·0	123	1·6	196·8	406·8
Delhi-Rohtak Road, Mile 3/4 . . .	178	1·5	267·0	173	1·4	242·2	509·2
Delhi-Gurgaon Road, *via* Basant. Mile 9/4.	51	1·5	76·5	19	1·8	34·20	110·7
Delhi-Gurgaon Road, *via* Mahrauli, Mile 7/8	132	1·4	184·8	29	1·6	46·4	213·2

STATEMENT No. 9.

Statistics regarding the average number of bullock carts carrying goods over 25 miles range, per 24-hours for six months from 1st October, 1934 to 8th April, 1935.

Census point.	Number of bullock carts on routes of length.				Remarks.
	25 to 30 Miles.	30 to 40 Miles.	Over 40 Miles.	Average total number of bullock-carts carrying commodities over 25 miles.	E. G. long distance predominantly non-agricultural carrying such and such commodities.
G. T. Karnal Road, Mile 4/4	14	..	9	23	Merchandise, Fruits, Building material, etc.
G. T. Meerut Road, Mile 3/5	19	7	23	49	Do.
Delhi-Muttra Road, Mile 4/7	5	..	..	5	Do.
Delhi-Rohtak Road, Mile 3/4	14	6	..	20	Do.
Delhi-Gurgaon Road, *via* Basant, Mile 9/4.	..	..	..	..	..
Delhi-Gurgaon Road, *via* Mahrauli, Mile 7/8.	..	..	1	1	Do.

STATEMENT No. 10.

Statistics regarding average total number of bullock carts per 24-hours for six months from 1st October, 1934 to 8th April, 1935.

Census point.	Agriculturists Carts.				Non-agriculturists Carts.	
	4-Wheeled.		2-Wheeled.		4-Wheeled.	2-Wheeled.
	Number with wooden tyres.	Number with iron tyres.	Number with wooden tyres.	Number with iron tyres.	Number.	Number.
G. T. Karnal Road, Mile 4/4 .	..	..	70	41	45	22
G. T. Meerut Road, Mile 3/5 .	..	..	77	38	164	56
Delhi-Muttra Road, Mile 4/7 .	..	..	120	30	109	24
Delhi-Rohtak Road, Mile 3/4 .	..	..	117	61	127	46
Delhi-Gurgaon Road, *via* Basant Mile 9/4.	..	..	42	9	19	..
Delhi-Gurgaon Road, *via* Mahrauli, Mile 7/8.	..	..	117	15	28	1

Mr. R. L. Sondhi.—Mr. President, Delegates and Gentlemen, I consider that the study of traffic is the most important feature of road engineering. I could, as a matter of fact, say that it is the foundation of the science of road-making.

But for traffic there would be no roads and but for roads our Congress would not have come into being; and, we would not have had the good luck to assemble here to-day in this magnificent Hall to enjoy the kind and lavish hospitality that His Highness the Maharaja of Mysore has been kind enough to extend to us and to visit so many places of interest.

I hope in the paper I have been able to impress the necessity of carefully designed traffic-surveys for different road-systems in the country.

For the economical design of a road surface, the most important factor is the estimation of the forces which would act on the road and this, as stated in my paper which I now formally introduce for your consideration and discussion, implies careful classification and examination of the traffic that is likely to use a particular road.

This may appear to suggest that I consider that exact forecasting of probable future volume and character of traffic is possible. I would, therefore like to clear this likely misapprehension and to add that with the methods of traffic-studies so far evolved it is not possible to achieve this object, though by persistent research and investigation in this direction, it may be possible to do so at a subsequent time.

The best possible basis for forecasting future traffic will be the actual traffic census figures collected over a long series of years; as, by their means it will be possible to establish 'trends' in traffic development.

The main object of this paper is to point out the value of traffic surveys under proper conditions and by implication to warn against expecting too much from a survey inadequately planned and carelessly managed.

I may add that a traffic survey is not an end in itself. It is a method of doing something: namely, of studying and diagonising an 'ailment' To be of proper use, we must firstly have some idea of what 'ailment' we are trying to diagnose or study; and, secondly, we must arrange for an expert analysis and interpretation of the data collected, by someone who really understands traffic.

To reiterate, therefore, such a survey involves three important steps:—

(1) Determination of what we want to study,

(2) Collecting the actual data, and

(3) The interpretation and conclusions.

(1) may look fairly simple, but (2) and (3) are definite 'Snags'; but to a certain degree the carrying out of all the three, for any road-system, would call for the best in the Engineer in charge and in the long run the utility of traffic survey work, as a part of road-planning, design and construction, must depend upon the interest of highway engineering profession and, in submitting this paper drawing conclusions from the study of traffic-survey conducted under the guidance of Mr. K. G. Mitchell, who takes a keen interest in advancing the roads-research in this country, I hope that requisite fillip will be given to the investigation of this important line of road-research all over India.

The following paper was next taken as read:—

Paper No. 15.

A STUDY OF THE RELATIONSHIP BETWEEN VEHICULAR TRAFFIC AND ROAD SURFACES AS AFFECTING THE SELECTION OF AN ECONOMIC *ROAD SURFACE*

By

H. P. Sinha, I.S.E., and A. M. Abbasi, Assistant Executive Engineer, Central Public Works Department, New Delhi.

It is a matter of general observation that iron tyred vehicles are the cause of early destruction of road surfaces owing to their unyielding nature and the intense pressure that is produced on the surface. The effect of a combined traffic of motor vehicles and bullock carts is found to be still more disastrous. There are, however, no definite data to determine the effect produced by different kinds of vehicular traffic on road surfaces, and an attempt has been made in this paper to arrive at such data. A study of the question of discordant relationship that must exist between vehicular traffic and road surfaces with reference to the adverse effect of the former on the latter is by no means an easy matter. It involves several factors, the determination of which needs close observations.

2. Several short lengths of different kinds of surfaces were constructed in the Provincial Division of the Central Public Works Department, New Delhi, during the last year. Details of the work and the specifications are described by Mr. A. W. H. Dean, Executive Engineer, in his paper which he read before the Indian Roads Congress held in December 1934. Some experiments have been conducted this year to study the effects and the pressure intensities which the different types of vehicles exercise on roads. These are described in the following pages. The results may need minor modifications in some respects on further observations.

I. *Effect of Iron-tyred vehicles on Road surfaces.*

3. In order to determine what the pressure on road surfaces under actual traffic conditions is, several tests were carried out for finding the bearing surfaces of the iron tyred wheels by taking impressions of their tracks on different kinds of road surfaces. For this purpose, two sheets of thin paper with carbon sheets placed in between were spread on the road surface and a vehicle was taken slowly over those sheets. An imprint of track was thus left on one of the papers as the wheel passed over.

4. In this way impressions of the wheel tracks of vehicles were obtained on (1) Cement concrete road, (2) rough and smooth surfaces of painted water-bound macadam roads, (3) heavy bituminous surfaces (Shelcrete, Trinimac, Premix), (4) stone sett pavement, and (5) medium heavy bituminous surface (2½ inch grouting). The impressions are recorded* in full size on plates Nos. 1 to 4 and 21 to 27.

5. In each case, the bearing surface was found by measuring from the impressions the mean width of the wheel track and multiplying it by the contact length of wheel with the road surface. The contact length was determined from another impression obtained by carefully lowering the wheel by means of a jack on similar sheets of paper.

6. The classified results of the tests are shown in table I. The ratio of bearing surfaces of the iron tyred wheels to the rim were found to be about 20 to 25 per cent. on stone sett pavement and concrete roads, 39 to 40 per cent. on heavy bituminous surfaces and 40 to 50 per cent. on smooth painted surfaces. In the case of stone sett pavements and rough painted roads, the bearing surface was found to be further reduced if the gaps in the impression of wheel track due to unevenness are deleted from consideration. The ratio then drops down to 17 per cent. only.

7. It has also been observed that the wheel track of the same vehicle on cement concrete road is narrower than that on painted or heavy bituminous surfaces, the reason being that, in the case of bituminous roads the surface yields to and is depressed by the pressure from iron tyres. This fact is also borne out by the impressions of the wheels of the same vehicle taken with and without load. The impressions on the concrete roads do not show any difference in the width of the wheel track, but on all bituminous surfaces the impressions of the wheels of the vehicle when loaded are wider than when unloaded.

On the stone setts and concrete surfaces the pressure intensity is found to reach a figure over 4,000 pounds per square inch under an ordinarily loaded bullock cart, because the bearing surface is very small. This result does not take into account the stresses due to impact of moving vehicle and the jolting of the wheels. The total stresses, therefore, on such roads are much greater and occasionally in excess of the compression strength of cement concrete. It is, therefore, no wonder that even a cement concrete road begins to show early signs of deterioration when subjected to heavy cart traffic.

8. As an illustration of this very detrimental effect of iron tyred wheels of vehicles on road surfaces, a graph of the outline of the surface of a 7″—5″—7″ concrete road which is only a year old is reproduced on Plate Nos. 28 and 29. The outline graph was produced on a paper stretched across the roadway by a profilograph mounted on a wooden beam set across the road. The profilograph consists of a steel roller, half an inch

* Specimens of these impressions are reproduced at the end of this paper. The original impressions were made available for inspection at the time of the Congress.

in diamater, fixed to the lower end of its daughting attachment which runs across the road on a carriage over the wooden beam by means of a mechanical device. A photo of the instrument appears on this page.

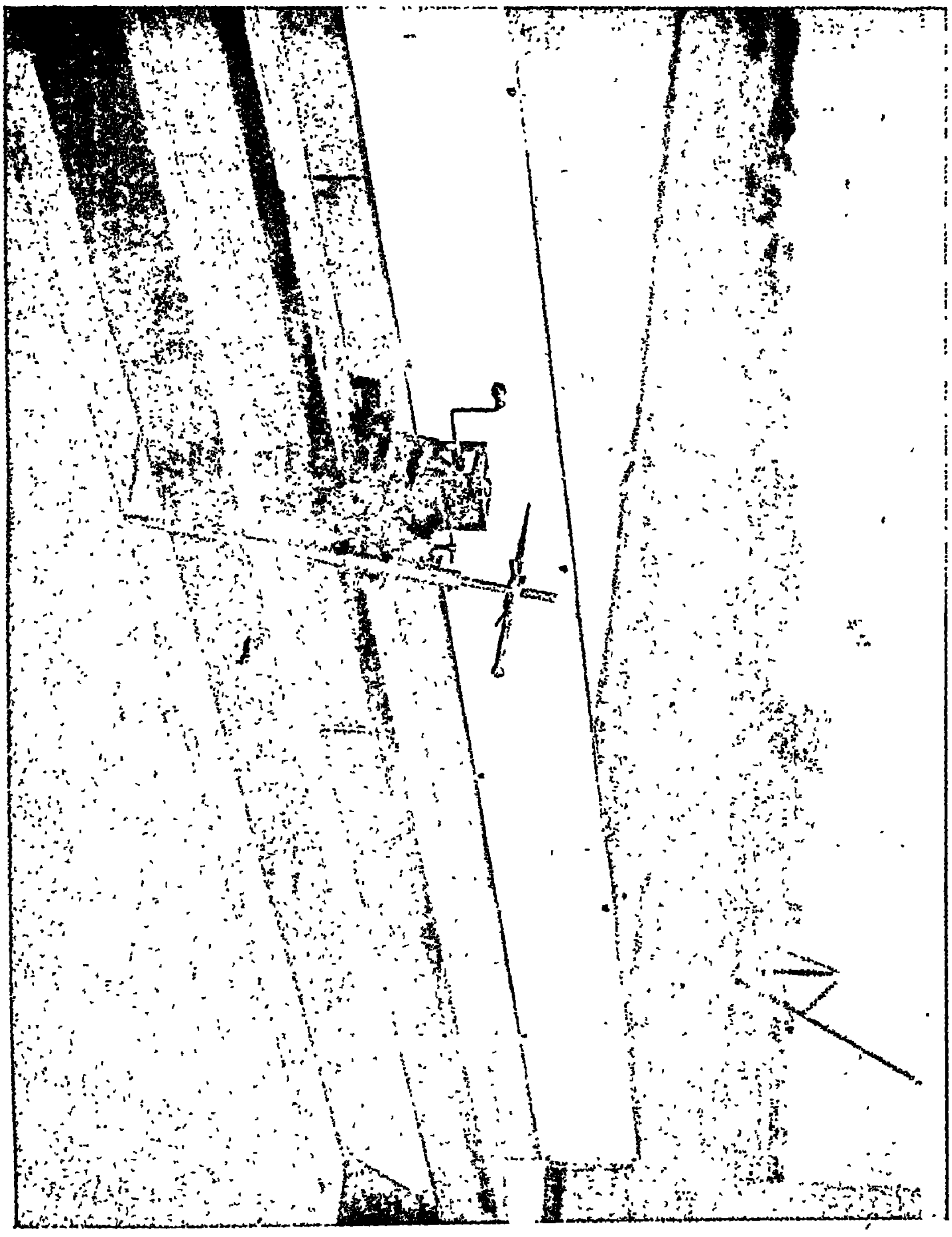


TABLE I.

Classified results of tests of the wheel tracks of vehicles on Provincial Roads, Delhi.

Date.	Name of Road.	Plate No.	Particulars of Road surface.	Class of Vehicles.	Weight in lbs. (w)	Diameter of wheel.	Width of wheel tyre or rim.	Period in use. wheel.	Bearing surface of wheel. Circumference of wheel in contact of surface. (c)	Bearing surface of wheel. Mean width of track. (b)	Ratio of bearing surface to rim surface.	Specific pressure $\frac{W}{4bc}$ lbs/□" for 4 wheeled $\frac{W}{2bc}$ lbs/□" for 2 wheeled.	Remarks.
1	2	3	4	5	6	7	8	9	10	11	12	13	14
					lbs.	Ft.							
4-8-35	Rohtak Road.	1	Cement Concrete Mile 2/1.	Village Cart 3 animals iron tyred.	3,444	4	2" (iron tyre).	1 Year	$\frac{3}{8}$"	$\frac{1}{2}$"	25%	4592	Loaded.
Do.	Do.	2	Shelcrete Mile 3/4.	Do.	3,444	4	Do.	Do.	$\frac{3}{8}$"	$\frac{3}{4}$"	38%	3061	Do.
Do.	Do.	3	Painted Road Mile 3/4.	Do.	3,444	4	Do.	Do.	2"	$1\frac{3}{8}$"	69%	626	Fresh painted surface.
Do.	Do.	4	Rough Road Mile 3/4	Do.	3,444	4	Do.	Do.	$1\frac{1}{2}$"	1"	50%	1531	Loaded.
7-8-35	Do.	5	Shelcrete Mile 3/4	Buffalo Cart iron tyred.	1,960	4-6"	$2\frac{1}{4}$" (iron tyre).	Do.	2"	$\frac{1}{2}$"	20%	980	Loaded.
Do.	Do.	6	Painted surface smooth	Do.	1,960	Do.	Do.	Do.	3"	$1\frac{1}{8}$"	50%	261	Do.
Do.	Do.	7	Cement Road	Do.	1,960	Do.	Do.	Do.	$1\frac{1}{4}$"	$\frac{3}{8}$"	15%	1494	Do.
Do.	Do.	8	Rough painted Road	Do.	1,960	Do.	Do.	Do.	$1\frac{1}{2}$"	1"	40%	560	Do.

Do.	Do.	9	Rough Road . .	Village Cart without iron tyre.	3,360	Do.	2½" (rim)	1½ Year	2¼"	1½"	66%	407	Do.
Do.	Do.	10	Painted Road . .	Do. .	3,360	Do.	Do.	Do.	2½"	1¾"	77%	384	Do.
Do.	Do.	11	Cement Road . .	Village Cart .	3,360	Do.	Do.	Do.	2"	1½"	55%	672	Do
Do.	Do.	12	Shelcrete Road . .	Do. .	3,360	Do.	Do.	Do.	3¼"	1¾"	61%	349	Do.
Do.	Do.	13	Shelcrete Road Mile 3/4	4 Wheeled with 2 Bullocks.	3,192	3'-3"	2½" (iron tyre).	3 Years	1¾"	¾"	30%	608	Do.
Do.	Do.	14	Shelcrete Road . .	Do. .	1,176	Do.	Do.	Do.	¾"	¾"	25%	627	Empty.
Do.	Do.	15	Cement Road Mile 2/1 .	Do. .	3,192	Do.	Do.	Do.	¾"	½"	20%	2128	Loaded.
Do.	Do.	16	Cement Road Mile 2/1 .	Do. .	1,176	3'-3"	Do.	Do.	¾"	½"	20%	784	Empty.
Do.	Do.	17	Shelcrete Mile 3/4 .	4 Wheeled Camel Cart.	3,360	4 ft.	2" (iron tyre).	1½ Year	1¾"	¾"	38%	815	Loaded.
Do.	Do.	18	Cement Road Mile 3/4	Camel Cart .	3,360	Do.	Do.	Do.	1½"	½"	25%	1344	Do.
Do.	Do.	19	Rough Road Mile 3/4	Do. .	3,360	Do.	Do.	Do.	1½"	½"	25%	1120	Do.
Do.	Do.	20	Painted Road Mile 5/1	Do. .	3,360	Do.	Do.	Do.	1¾"	1½"	52%	448	Do.
9-8-35	Meerut Road.	21	Trinimac surface Mile 3/6.	4 Wheeled with 2 Bullocks.	4,816	3 ft.	2½" (iron tyre).	1 Year	1¾"	1½"	45%	612	Do.
Do.	Do.	22	2½" Shelcrete .	Do. .	4,816	Do.	Do.	Do.	1½"	⅞"	35%	786	Do.
Do.	Do.	23	Grouting with hot Asphalt Socony Mile 2/4.	Do. .	4,816	Do.	Do.	Do.	2"	⅞"	30%	803	Do.
Do.	Do.	24	2½" Hot Socony Premix Mile 1/3.	Do. .	4,816	Do.	Do.	Do.	1½"	1"	40%	803	Do.
Do.	Do.	25	Cement Road Mile 1/4 .	Do. .	4,816	Do.	Do.	Do.	1½"	½"	20%	2140	Do.
Do.	Do.	26	Stone sett West end of Jumna Bridge.	Do. .	4,816	Do.	Do.	Do.	½"	3/5"	23%	4013	Do.
Do.	Do.	27	Painted Road Bela Road.	Do. .	4,816	Do.	Do.	Do.	2½"	1½"	50%	385	Do.

* Plates are not reproduced. See footnote to page 30.

9. The depressions, *a, b, c and d*, on the graph represent the tracking produced on the road surface by the iron tyred bullock cart traffic. The depth of the tracks in certain cases is as much as a quarter of an inch, and this has developed in less than a year. It is thus clearly demonstrated that even a cement concrete surface is not sufficiently resistant to traffic of heavy bullock drawn vehicles fitted with iron tyres, and that as long as the existing kind of wheels are used in the country, the construction of cement concrete roads is bound to prove wasteful.

10. Similar graphs of bituminous surfaces were obtained which do not show tracking. The reason lies in the plastic nature of bitumen which prevents the wearing of surface but allows further compaction. The graphs are reproduced on Plates Nos. 29, 30 and 31.

11. The destructive effect of bullock cart traffic is also aggravated by such climatic conditions when a rapid fluctuation of temperature may suddenly take place. During the last winter some of the roads in this Province experienced heavy frost. This had the effect of increasing the rigidity of bituminous material on the surface, and in consequence it crumbled under the hard inelastic wheels of bullock carts.

II. *Effect of pneumatic tyres on road surfaces.*

12. The bearing surface of the pneumatic tyres of motor vehicles were determined by measuring impressions taken of the wheels of standing vehicles by the same method as employed for taking those of the iron tyred vehicles. The intensities calculated of the heaviest load of a motor-lorry did not amount to more than 50 pounds per square inch, which only slightly exceeds the air pressure inside the pneumatic tyre. Compared to this the intensity in case of iron tyre vehicle is 90 times more!

13. In this country where the bullock cart traffic has a great preponderance over all other traffic, the introduction of motor vehicles had brought out new difficulties in the up-keep and maintenance of water-bound macadam roads, a solution for which was, at one time, found in giving a tar or bituminous treatment to the surface. But the traffic having further increased the equilibrium which was thus temporarily established has been lost. Under the conditions prevailing in the Delhi Province a painted surface does not last long. Its economic life is not more than two years. The cost of maintenance after this period goes up and it then becomes an unprofitable item of road budget. When this stage is reached the bullock cart traffic by its excessive intensity causes rapid decay of the painted surface while the fast moving motor vehicles following, sweeps up the decayed material and enlarges the pot-holes in the underlying water-bound macadam surface. No improvement is then possible without breaking up the macadam coat and remetalling it.

III. *Economic Selection of Road surface.*

14. For an economic selection of a road surface the determination of pressure intensities which each type of vehicle exercises on the surface is alone not sufficient. It is also necessary to know the amount of traffic and its character.

Recently, for the first time in the history of this country, a continuous census of traffic was taken for six months on Provincial roads and statistics of the volume of vehicular traffic, and its weights have been collected. A summary of the traffic is given in table II.

TABLE II.

Statistics regarding average total traffic for 24 hours for six months from 1st October 1934 to 8th April 1935, Delhi Province.

Census point.	Width of metalled surface in feet.	Motor Transport.		Non-Motor Transport.		All Vehicles.		Weight and number of Vehicles per yard width of metalled surfaces per 24 hours.	
		No. of Vehicles.	Total weight in tons.	No. of Vehicles.	Total weight in tons.	No. of Vehicles.	Total weight in tons.	Weight per yard (in tons).	Number per yard.
G. T. Karnal Road Mile 4/4 .	12	86	213·69	310	354·10	405	567·79	141·99	101
G T. Meerut Road Mile 3/5 .	24	268	697·05	440	586·00	709	1283·45	160·43	89
Delhi Muttra Road Mile 4/3 .	18	258	776·37	385	519·46	643	1295·83	215·97	107
Delhi Rohtak Road Mile 3/4 .	12	124	381·19	444	391·66	568	772·85	257·62	142
Delhi Gurgaon Road *via* Basant Mile 9/4	12	113	312·88	108	160·33	220	473·21	157·73	55
Gurgaon Road *via* Mahrau'i Mile 7/8	24	97	165·10	382	590·00	430	755·00	94·37	105
Old Rohtak Road Mile 3/4 .	18	20	48·60	562	835·70	582	884·30	147·39	97

15. We have likewise the results of the experiments that have been carried out in the past few years with heavy, medium and light surfaces. The table appended below has been prepared to show the construction cost and economic life under different traffic conditions.

TABLE III.

Road cost other than upkeep cost per yard width per mile. Amount of vehicular traffic.

No.	Kind of road surface.	Construction cost (Mc).	Residue value (rc).	Amount of vehicular traffic per yard width of road.	Economic life.	Reserve fund required.	Unit reserve (p).	Annual reserve (rc).	Interests at 5 per cent. (rmc).	Upkeep cost of road other than surface (mu_1).	Road cost other than upkeep cost.
1	Surface treatment with bituminous material	950	475	100	2	475	0·154	221	47·5	250	518
2	Shelcrete 2½ inch .	3,406	1,703	150	4	1,703	0·221	376	170·3	250	796
3	Shelsheet 1 inch. .	1,742	871	50	3	871	0·302	264	87·1	250	601
4	Tar-carpet with seal. coat, 1 inch. . .	1,346	673	50	1	673	0·952	641	67·3	250	958
5	Tar-carpet 1½ inch .	1,901	950	100	1	950	0·952	905	95·0	250	1,250
6	Tar-carpet 2½ inch .	2,930	1,465	150	1	1,465	0·952	1,395	146·5	250	1,791
7	Cement Concrete .	7,920	3,960	150	8	3,960	0·099	395	396·0	250	1,041
8	1½ inch Armour coat .	2,376	1,188	100	3	1,188	0·302	359	118·8	250	727
9	1 inch Tar Bitumen .	2,376	1,188	100	3	1,188	0·302	359	118·8	250	727

The mathematical formulæ which are at present applied to obtain the road cost for effecting a comparison of variable initial values of different kinds of road surfaces are many but the one adopted here stands out clearly from the others. The standard of economy is the amount annually required for the upkeep and maintenance of a surface permanently, inclusive of interest charges.

$$\text{Road cost} = (Mc - Rc)\ p + Mu + rMc.$$

$$\text{When and } p = \frac{r}{(1+r)\left\{(1+r)^n + 1\right\}}$$

Mc = Construction cost of a surface.
Rc = Residue value.
Mu = Up-keep cost.
n = number of years of economic life.
r = Interest on Re. 1 in one year.

TABLE IV.

Upkeep cost of surface (mu_2).

Amount of mixed vehicular traffic per yard width of road.

Motor-vehicles 30 per cent.; Non-motor vehicles 70 per cent.

No.	Kind of Road surface.	50 Mixed traffic.	100 Mixed traffic.	150 Mixed traffic.	Non-motor vehicular traffic only. 94 Nos. bullock carts.
1	Surface treatment with bituminous material .	*Nil*	200	400	..
2	Shelcrete, 2½ inch . .	*Nil*	*Nil*	*Nil*	250
3	Shelsheet 1 inch . .	140	280	420	..
4	Tar-carpet 1 inch .	140	280	420	..
5	Tar-carpet 1½ inch .	Failed in the 1st year.	..	..	..
6	Tar-carpet 2½ inch .	..	..	..	200 Failed in 1st year.
7	Cement Concrete . .	*Nil*	*Nil*	*Nil*	*Nil.*
8	1½ inch Armour Coat .	*Nil*	20	..	..
9	1 inch Tar Bitumen .	..	20	..	..

TABLE V.

Road cost per yard width per mile.

Amount of motor and non-motor traffic (Delhi Province).

No.	Kind of road surface.	50 Mixed traffic.	100 Mixed traffic.	150 mixed traffic.	Non-motor vehicular traffic only. 94 Nos. bullock carts.
1	Surface treatment with bituminous material .	518	718	918	..
2	Shelcrete 2½ inch. . .	796	796	796	1,046
3	Shelsheet 1 inch . .	741	881	1,021	..
4	Tar-carpet 1 inch . .	1,098	1,238	1,378	..
5	Tar-carpet 1½ inch . .	1,250	1,250	1,250	..
6	Tar-carpet 2½ inch . .	1,791	1,791	1,791	1,991
7	Cement Concrete . .	1,041	1,041	1,041	1,041
8	1½ inch Armour coat .	727	747	..	..
9	1 inch Tar bitumen . .	727	747	..	..

16. The term economic life is used to denote that period in the life of a surface in which the cost of its up-keep and repair remains steady and the smallest. When the maintenance cost goes up the economic life ends.

17. Columns 7 to 12 in Table III give the amounts annually required for permanently securing the effective maintenance inclusive of interest and renewal charges of the treatments without requiring additional funds. Table IV shows the up-keep cost that has been found from the experience gained hitherto of the different kinds of road surfaces under known traffic conditions. Table V is a consolidated table and gives the comparative figures of the total road cost of the type of road surfaces that have been selected with an ample margin of safety for the number of vehicles shown against them. The three tables cover the economic process for effecting a comparison of variable initial values of these types.

18. The comparison of road costs is by no means unconnected with the transport cost which should be an important consideration in road making. I have not had yet an opportunity to study the effect of the different road surfaces on the cost of transport for want of suitable means. In any case this consideration should not be ignored.

19. *Conclusion.*—On account of the use of types of wheels in vehicles in India which are not improved up-to-date, the economic life of all types of road construction in this country is about one-half of such life in other countries. The road cost in Table V will, on that account, be found very high for all the 9 types shown therein.

20. It is, therefore, imperative that suitable legislative and administrative measures for the control of the traffic design of the vehicles and their wheels may be adopted to restrict the intensity of pressure coming on road surfaces.

21. A suitable technical measure would be the laying of stone sett shoulders on all the important roads, for use of iron tyred vehicles.

22. The figures of cost of different road surfaces, given in table V show that when mixed class traffic exists in the proportion of 70 non-motor to 30 motor vehicles a surface treatment is cheaper for a volume upto 100 vehicles per yard width of road, a 2½ inch Shelcrete from 100 upto 150 vehicles. For exclusive bullock cart traffic a cement concrete road can stand only upto about 100 vehicles per yard width of road.

Mr. R. L. Sondhi.—In the absence of Messrs. Abbasi and Sinha I consider it a great privilege and honour to introduce their paper entitled "A Study of the relationship between vehicular traffic and road surfaces as affecting the solution of an economic road surface". Some of us, including myself, may not perhaps agree with some of the conclusions that the authors have made; but I hope you will all join with me in thanking the authors for the trouble taken by them in attempting to determine the destructive effect of vehicular traffic, particularly iron-tyred bullock carts. I will be glad to communicate to the authors any criticisms that the delegates may like to make and the replies of the authors thereto will be included as correspondence in the proceedings of the Congress.

The following paper was taken as read:—

Paper No. 16.

TRAFFIC CENSUS AND ROAD DIAGRAMS.

By Lt.-Col. W. deH. Haig, D.S.O., United Provinces P. W. D.

The first concerted attempt at taking a traffic census in the United Provinces was made in 1930, though prior to that one or two local efforts had been made. The census was taken on one day only and the count was from 4 A.M. to 8 P.M., vehicles were counted under the following heads:—

(*a*) Bullock carts, laden,

(*b*) Bullock carts, empty,

(*c*) Lorries or Buses,

(*d*) Motor cars, and

(*e*) Tongas and Ekkas.

The counting was done by road mates and coolies, though in some instances subordinates also assisted, and the method of recording numbers was to make a stroke with a pencil in the appropriate column of a ruled form. The headings of the columns were written in by the subordinate either in Urdu or Hindi according to the language of the mate concerned. The average weight to be attributed to each vehicle was determined very roughly by taking the mean of the weights reported for their localities by the Executive Engineers.

2. The 1930 census revealed the fact that the operation was not nearly so difficult as had been imagined and there appeared no reason to suppose that grave inaccuracies had occurred though obviously, it would be unsafe to assume that the figures were correct within a small percentage. The cost of taking the census was negligible since it was taken only at 116 different spots and no extra establishment was employed.

3. With the great reduction of work consequent upon the financial situation which developed in 1932 preparations were made for carrying out a much complete and elaborate census. Executive Engineers were instructed to prepare diagrammatic maps of their divisions in which each road was divided into sections such that the traffic throughout a section could be

considered as approximately constant. The dividing line between sections was usually a road junction, an important village, a railway station or perhaps the limits of a brick field area, and each section included one census station. In town areas it was, of course, impossible to have a census station to cover every variation in traffic intensity and stations were therefore placed in what were considered representative spots. The sections and census stations having been decided upon, instructions were issued that a count should be taken once a month for a year and that in places where there was a periodical fair or "mela" one such day should be included in the years figures but that the other eleven occasions should be chosen so as to avoid such fairs. The actual date or day of the week on which the census was to be taken was not to be regarded as fixed but was normally to be in the first week of the month unless a variation was necessary to avoid abnormal traffic.

4. In the original orders issued, the duration of the census was given as twelve hours but the actual times were left to the discretion of the Executive Engineer concerned and were to be selected so as to give the maximum volume of traffic; the hours between which the count was made varied with the time of year and the habits of the locality. Later on it was realised that in some places there was considerable night traffic whereas in others, there was practically none and that, therefore, a comparison of twelve hour figures would, in certain cases, be misleading. Instructions were therefore issued for the census to be taken for 24 hours. The fact that a 24 hour census would need more personnel and that the danger of error would be increased owing to the probability of men going to sleep, was appreciated but it was thought that the inaccuracies thus introduced would be of less consequence than those resulting from a 12 hour census.

5. The classification of vehicles was made rather more elaborate than before and these were divided into:—

Motor Traffic.

(*a*) Lorries and buses, solid tyres,

(*b*) Lorries and buses, pneumatic tyres,

(*c*) Motor cars,

(*d*) Miscellaneous (Motor cycles and side cars etc.).

Non-Motor Traffic.

(*e*) 4 wheeled bullock carts,

(*f*) 2 wheeled bullock carts with one animal,

(*g*) 2 wheeled bullock carts with two or more animals,

(*h*) Passenger vehicles with one animal,

(*i*) Passenger vehicle with more than one animal.

I may say at once that experience has shown that this very complicated classification is not only cumbersome but quite unnecessary and, as will be seen later, a very much simpler classification is now being adopted.

6. For recording the actual count on the ground forms* were printed giving in illustration, as well as in Hindi and Urdu wording, the description of the type of vehicle to be recorded in each column. It will be observed

* Not reproduced here.

that no distinction was made between laden and unladen vehicles as it was thought that the addition of several more columns would be quite impracticable; in applying average weights, however, it was assumed that a proportion of vehicles were empty and the average weight attributed to each class was modified accordingly. The monthly figures for each census station were then recorded in bound books printed for the purpose and the average for the year computed on completion. Once more the weights attributed to each class of value were the same throughout the province.

7. This census was taken for rather more than two years but the figures for the first few months were ignored as they were for 12 hours only. An abstract of the figures obtained is as follows:—

From 0 to 500 tons total traffic	1,827 miles
„ 500 to 1,000 tons total traffic	940 miles
„ 1,000 to 1,500 tons total traffic	279 miles
„ 1,500 to 2,000 tons total traffic	78 miles
„ 2,000 to 3,000 tons total traffic	40 miles
„ Over 3,000 tons total traffic	27 miles
	3,191 miles

8. The figures have proved very interesting. Firstly they have indicated that it is quite impossible to judge the volume of traffic by occasional observation and it was found that miles where we had considered the traffic very heavy were, in fact, subjected to only medium or even fairly light traffic. This gave rise to suspicions that the counts were definitely inaccurate and that, probably, some gangs had slept all night and entered fictitious figures while others had been reasonably conscientious and had entered most of the vehicles which had passed. Check, of course, is neither easy, nor attractive and with many officers some suspicion still remains. My own feeling is that on the whole the figures are sufficiently accurate relatively to afford a fair comparison but that in any places where the figures appear inordinately small, or large. these should be checked by a subordinate or Assistant Engineer taking a count on one day and comparing it with the count on the corresponding day last year. The figures would not be the same but any great difference might be held to confirm the suspicion referred to.

9. There were 387 census points in a road system of approximately 3,200 miles and the question then arose as to the best method of arriving at the figures to attribute to the intervening miles. I have already explained that the roads were divided into sections where the traffic was, more or less, constant but it remained for decision whether this should be accepted as correct or whether it would be better to interpolate figures according to the merits of each case. Eventually the latter method was adopted because in certain instances, notably brick kiln areas, the volume of traffic in a section varied from a maximum at one end to a minimum at the other. The figures ultimately obtained have been plotted on a diagrammatic map, to which I will refer later, and have since been used for two main purposes *viz.*, (1) to afford some check on the type of road surface proposed for different miles in our new road reconstruction programme and (2) in an endeavour to ascertain what traffic factor chiefly governs the life of a painted mile.

10. Reference to our road record shows that the life of a painted mile, that is the period between original painting and repainting, varies from one and a half to six years; and it was hoped that by tabulating the figures of life and traffic we would be able to show that the life depended either on total tonnage or on bullock cart tonnage; it was also hoped that we would be able to fix within rough limits the tonnage (either bullock cart or total) which a painted road can withstand without requiring repainting at uneconomically short intervals. Unfortunately these hopes have not been fulfilled; in some places painted miles have lasted 4 years under about 1,000 tons bullock cart and, say 1,200 tons total traffic while in others under similar, or even less, traffic, they have only lasted two years. In some places miles have lasted six years under light traffic and in others only three. The number of variable factors is great but different analyses based on such factors as—

(1) different kinds of painting material,

(2) different quantities of painting material,

(3) different sizes or quantities of grit,

(4) different qualities of grit,

(5) varying period between consolidation and painting,

(6) time of year of painting, etc., etc.

have failed to give us any definite standard by which to judge how long a painted mile may be expected to last or a traffic figure beyond which paint is not economical. There are, however, very definite indications that the sole factor of any importance in this province is the bullock cart traffic and the consensus of opinion is that the life of a painted mile varies according to bullock cart tonnage combined with some function of the percentage of iron tyres and the maximum wheel load. The two last items are clearly of great importance; 2,000 carts each weighing half a ton will obviously do less damage to a painted road than 500 carts weighing two tons each and 2,000 tons carried on iron tyres will cause more damage than the same weight on broad wooden wheels. The average weight of carts varies, not only with each locality, but also with the time of year. The percentage of iron tyres might be considered as constant for each locality but actually the proportion varies with the time of year owing to the fact that at certain times there is a larger number of carts coming in from villages on *katcha* roads and, therefore, a larger number of wooden wheeled vehicles.

11. Since we have not yet got figures giving the percentages of iron and wooden tyres in different localities, or detailed information as to the variation in loads, we cannot at present take these factors into consideration in deciding what volume of traffic is too great for an ordinary painted road but, on the available information, the general opinion is that it is not economical to adopt a painted surface for a road carrying more than about 1,000 to 1,200 tons total traffic or, perhaps, 800 tons of bullock cart traffic. Moreover, in particular places, such as roads leading from brick kilns to the town, where loads are very heavy and wheels invariably iron-tyred, 500 tons of bullock cart traffic is probably the limit for a painted surface.

12. In this province the opinion generally held is that if traffic is more than a painted road will stand for three years without repainting then the only economical form of surface is concrete; for this reason it is vitally

important to arrive at a "yard stick" by which we can measure traffic and determine whether paint will fail or be successful. With this object in view preparations are being made for a new census which will take into account maximum wheel loads, nature of tyre and total numbers of bullock carts. This new census will be taken only on miles which are already painted so that the figures obtained can be considered *vis a vis* the known behaviour of the mile and, once more we cherish the hope that some definite results will be obtained. The instructions for the new census are, briefly as follows:—

(1) Bullock carts only will be counted.

(2) Carts will be regarded as in two groups—heavy carts and light carts. This will require the exercise of a little common sense but in most places there are carts which carry heavy loads such as bricks, sugar cane, stone, etc., and others which carry definitely lighter loads.

(3) In a preliminary investigation the average weight of the heavy class and of the light class will be determined by actual weighing with a machine of the "Loadometer" type. This investigation will be made for each census point separately. Empty carts will be included in the "light" class.

(4) In any cases where experience has shown that one side of a mile requires re-painting in a very much shorter time than the other, a separate census will be taken for the traffic in each direction.

(5) Iron tyred and wooden tyred carts will be counted separately.

(6) The census will be taken for 24 hours.

(7) The census staff will be of a more educated type than that previously used and, since the number of points will be very greatly reduced it will be possible to engage staff specially for the purpose.

13. I have referred above to the plotting of census figures on a diagrammatic map. The first road diagram for this province was made to show at a glance the type of surface and width of metalling of every mile of the road system; it was made because reference to tabulated records of 3,000 miles is a tedious business and one which fails to impress the mind. A diagram, on the other hand, can be hung on the wall and referred to in a moment and, in addition, gives visual information much of which is automatically registered in the memory. Attached to this note is a reproduction of part of the diagram referred to: the linear scale is 8 miles to the inch and the width of the metalling is indicated by 1/8th of an inch, for a 9 foot road, 2/8th of an inch for a 12 foot road, 3/8th of an inch for a 16 foot road and 4/8th of an inch for roads 20 feet wide, or more. The conventions adopted for the type of surface were chosen so that they should, so far as possible, convey the nature of surface to the mind without having to memorise the colours etc., thus black in any form indicated bitumen or tar; white, kunker and burnt sienna, stone.

14. The actual size of the diagram for the United Provinces measures six and a quarter feet by five and three fourths. After making this diagram

it was thought that the scale might be reduced without unduly sacrificing the ability to give information; therefore, for the traffic census diagram, the scale was made 16 miles to the inch and variations in width of metalling were ignored. The census figures were divided into groups of—

0 to 500 tons,

500 to 1,000 tons,

1,000 tons to 1,500 tons,

1,500 tons to 2,000 tons,

2,000 tons to 3,000 tons, and

over 3,000 tons.

The groups were distinguished by different colours. Three sheets are attached to this paper, upon which are reproduced copies of the resulting diagrams. Since it was thought that blank diagrams would be of use in the future for such purposes as new census figures, reconstruction programmes, etc., the diagram was printed and is now available for any of the above purposes. Where it is required to show widths of the metalled surface it has been found that this can be done by (rather laboriously) adding extra lines as in the first diagram made, or by figured dimensions along the road lines.

Rai Bahadur Chuttan Lal.—I introduce this paper on behalf of Lt.-Col. Haig, who, for unavoidable reasons, could not be present at to-day's Congress. When this paper was written by him, Col. Haig did not know that a Technical Sub-Committee had been appointed by the General Committee of the Indian Roads-Congress to report on the standardisation of the method of taking traffic census. That Committee has since submitted its report and its recommendations have in a way been approved by the Council. It will be seen that the recommendations are in all essential respects in agreement with the suggestions made by Col. Haig in his paper excepting perhaps with regard to taking census of motor cars. But in introducing his paper, what I would like to emphasise is this: that the traffic censuses in the United Provinces are being taken only on those miles which have been already treated in some way or other. The author of the paper should not be understood to hold the opinion that motor car traffic does not in any way deteriorate or affect the wearing surface of water-bound and treated roads.

I shall be glad to answer any criticism which any member may make on this paper.

DISCUSSION ON PAPERS IN GROUP 1:—TRAFFIC CENSUS AND USE OF RESULTS THEREOF.

Mr. A. Lakshminarayana Rao.—Mr. President and Gentlemen before uttering a word of criticism, I feel it my duty to add my humble congratulations to the author of the paper for the admirable analysis he has given of the traffic on roads around Delhi, which will help other engineers greatly in making a similar analysis. But some of the conclusions arrived at by the author do not appear to be quite correct. The paper is very carefully written and the author may be able to elucidate more clearly certain points raised and I request the author to take the following remarks in the spirit of an enquiry. In paragraph 17 it is stated that the intensity of pressure on the surface of contact in the case of a bullock cart with iron tyres is over 4,000 pounds per square inch. Statement 8 of the author shows that the ascertained weight of the vehicle is 1·65 tons or 3,696 pounds on two wheels or 1,848 pounds on each wheel. For this load to give a stress of 4,000 pounds. per square inch, it is necessary that the area of bearing is less than half square inch. The width of a wheel tyre is said to be 2 to 2½ inches. How this gives an area of contact of ½ inch, unless the wheel gets upon a stone, passes one's comprehension and I am afraid the pressure of 4,000 pounds, per square inch requires much more scrutiny.

Next, the bullock cart is described as destructive in paragraph 29 and the replacement of iron tyre by a rubber tyre is suggested as a means of reduction of destructive factors. This shows that the author considers the tyre to be the primary factor and ignores speed as a destructive agency. This does not appear to stand the test of scrutiny. Incapacity to resist the compressive stress due to the static load is not at all the cause of the failure of the road surface except on newly made roads, but incapacity to resist the horizontal stress caused by the frictional resistance of the surface on which the vehicle moves is the cause of the failure of most of our roads. This frictional resistance varies, as everyone knows,

with the velocity of the vehicle and the weight it carries; and, considered in this light, the overloaded motor lorry carrying as much as 6·38 tons, as per statement 5, and moving with a speed of probably 25 to 35 miles an hour seems to be the worst enemy of the road masquerading in the garb of a friend and it appears that it is high time to fight out this enemy. The author of the paper has in a way hinted this in paragraph 26 but the constant use of the epithet "destructive" for the bullock cart does not make the views of the author clear and I request him to throw further light on this aspect of the question.

The Statement No. 1 shows that the weight per yard width of load on the metalled surface was obtained by dividing the load by the width of the road. As the traffic is almost always restricted to what are called traffic lanes, it appears that it will be more accurate to divide the load by the width of traffic lanes.

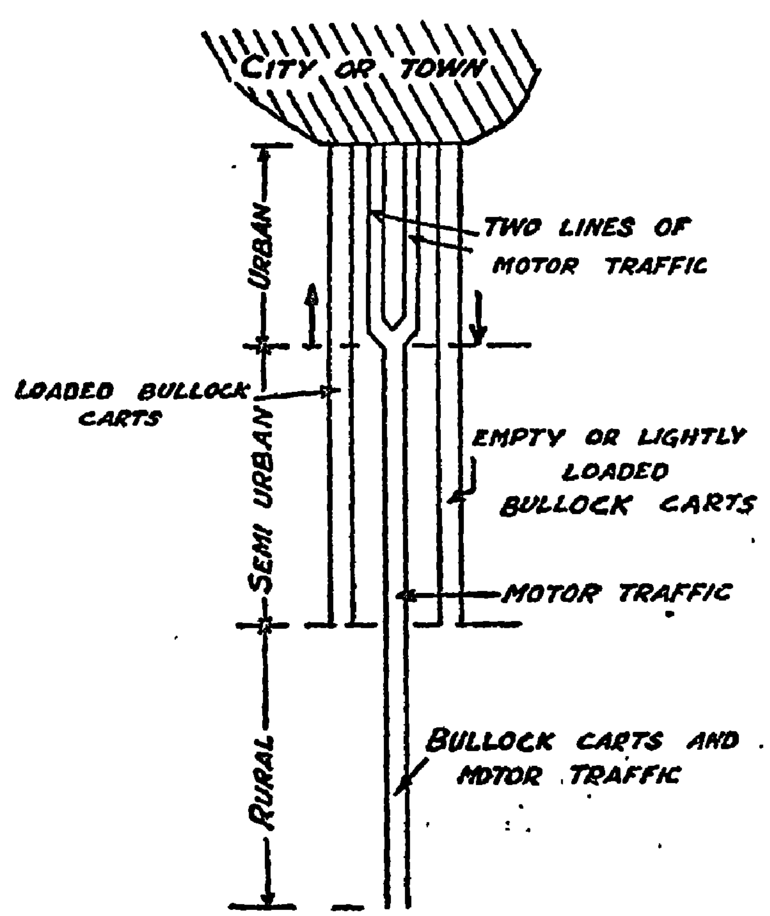
Chairman.—In this paper, there are one or two points on which I wish to make my comments. As the previous speaker said, destruction of roads by bullock carts is one of them. As regards this, I am afraid, so far as the water-bound macadam surface is concerned, it is not the bullock cart that would destroy this. Because, in Mysore itself and elsewhere also, it has been a common matter of observation that we see miles and miles of deep ruts. The surface has not been renovated or renewed for years together in some places and even there the road is not broken up. It is the slow but strong grinding action of the bullock carts that has made two deep ruts. The middle portion is intact and every other place is intact except the two ruts that they have formed. That does not show that the bullock carts are destructive to macadam roads. It rather shows that there is the slow grinding action of the bullock carts which only produces rutting and not disturbance of the road surface. But the bullock cart is extremely destructive to modern surfaces, especially asphalt surfaces, because the intensity of load on the road is very heavy and in hot weather the asphaltic substance becomes soft, the whole thing sinks and you find big wheel marks cutting into the road. The bullock cart is destructive to modern surfaces, especially asphaltic surfaces, whereas motors are very destructive to macadam surfaces; because, there the action of the driving wheel,—the rear wheel—especially, disturbs the metal and breaks it up. It has a rasping action on the surface. These two things are fundamentally different factors in the making and maintenance of roads.

I differ from the very widely held opinion, especially of my very esteemed friends, Col. Smith and Mr. Ormerod and the Indian Roads Association. They always say that bullock carts are most destructive to road surfaces. What I say is that they are destructive to modern road surfaces and not to the old macadam surfaces.

This leads me to the other question of "The traffic intensity". In the case of traffic intensity, it is a matter of common observation, as the previous speaker said, that the wheels are confined to two narrow strips of road and do not use its whole width. So, at the outside, if you measure the whole road, you will find only 1½ feet under each wheel subject to heavy wearing. The two wheel-tracks together will be one yard in width. This gives us the traffic intensity for one yard width. This is a

more correct way, than deducing the weight or number of carts per yard width of whole surface for expressing the intensity of traffic. All that we have to see is the number of vehicles on the road and the total weight. I want to suggest that as the standard way of expressing the traffic intensity.

There is one other point with regard to traffic intensity. We have got in the case of our rural roads, one line of traffic with long stretches of double wheel tracks. The wheel tracks are used by all kinds of traffic, bullock cart as well as motor. As we approach a town or city, we usually see in the semi-urban zone the bullock carts keeping off the centre and go to the sides so as not to be disturbed constantly by the fast moving motor vehicles. As we approach the towns and get into the busy urban zone there will be found four distinct lanes of traffic, two of bullock carts, on either side and two of to-and-fro motor traffic, as illustrated in the following sketch plan. This is clearly the case on the Bandra-Godbunder Road near Bombay; and also near Bangalore as you noticed the other day.



PLAN

The incoming (left hand side) bullock cart traffic will be much heavier in intensity than the outgoing (right hand side). Construction of the road on one side will have to be different from the other. And these two cart lanes will have to bear different intensities of traffic than the middle portion which will be for fast-moving traffic. I suggest this method for adoption in future traffic census because on that depends the future proper designs of our roads.

Mr. H. Hughes.—Mr. President and Gentlemen; a traffic census of all vehicular traffic on main roads was made in Burma in 1933. There are one or two practical points in connection with it which may be of interest for carrying out a similar census. The first point is that traffic varies from hour to hour. The traffic was counted hour by hour and it was found that not only does it vary, but that a lot of traffic is carried by carts at nights so that any reference, as one frequently sees in engineering journals, to traffic per hour would be highly misleading in case of particular conditions in Burma and I suppose in India also. Not only is there hourly variation, but variation month by month during the year. It is the custom of the Buddhists not to undertake a journey, if possible, during the rains and very few people travel at that time of the year. The heaviest traffic is after the crops are reaped during the early part of the dry weather, so that one has to be careful in selecting the days when a count is taken in order to arrive at a fair average embracing all the variations throughout the year. The system that was adopted was to count the traffic for three days continuously at four seasons of the year in order to try to embrace these varying conditions, and arrive at a fair average figure. The traffic, as I think is pointed out in one of the papers, has to be counted during the whole of the 24 hours. We found that counting traffic for 12 hours and then making some allowance for the remainder of the day was not a satisfactory method.

Then, having determined the numerical count, the next difficulty was to convert the figures to tons. There were no weight bridges on the roads but it was possible to arrive at a rough average by weighing at Railway Station goods yards, the different classes of vehicles that are met on the roads. The average weight took into account the usual proportion of loaded and unloaded vehicles.

Having got so far, the next thing was to present this information in a form which could be easily grasped and it was decided to draw a diagrammatic map of the province, on which the roads were represented approximately in their alignment from town to town. The width of the road was plotted to represent the computed yearly traffic. In the diagram accompanying paper 16, the road from town to town is shown as a straight line. I am not suggesting that it is not a suitable way of doing it. But in the Burma map the actual alignment of the roads was shown. A linear scale of 16 miles per inch was adopted in order to get the whole of Burma on a reasonable sized sheet of paper.

For the width of the road it was impossible to select any natural scale which would show both the maximum and the minimum traffic. So, various alternatives were considered, and one of them was to represent varying traffic by means of different symbols or colours as adopted by the author of this paper on traffic census and road diagrams but it was abandoned owing to printing difficulties. The method finally adopted,

which is not altogether satisfactory, was to make the width of the road proportional to the square root of the traffic. With this type of scale it is difficult to appreciate the variation in traffic.

A differentiation was made between animal-drawn and self-propelled vehicles. Pedestrians were not counted.

One more difficulty which is peculiar to the province (Burma) is that there are berm roads for carts by the side of embanked roads. A certain proportion of the bullock cart traffic uses these roads, so that from the figures obtained, it is difficult to arrive at any intensity of traffic on the surfaced portion of the road, because it was too difficult for our enumerating staff to attempt to record separately the vehicles using the main part of the road and the berm road.

In the beginning of Mr. Sondhi's paper, he says that the object of roads is to serve traffic. This is of course ultimately correct, but there are certain roads which are intended for administrative and military purposes and these do not justify themselves from the traffic point of view. When the diagram was completed, it was seen that the volume of traffic on certain roads did not justify their maintenance; but they are necessary for administrative purposes.

I notice that figures in statement 1 of Appendix II of Mr. Sondhi's paper are given correct to 2 places of decimals. This is perhaps an unnecessary refinement.*

Mr. G. Reid Shaw.—There are just one or two small points to which I desire to refer.

In para. 26 of paper No. 14 reference has been made to overloading of motor lorries and buses. We have had the same difficulty in Assam and when prosecutions have been instituted we found that the fines imposed amounted to Rs. 5 or Rs. 6. A lorry or bus carrying an overload of, say, one ton on a fifty mile run earns anything up to Rs. 15 or Rs. 20 on the overload and it was therefore well worth the owner risking an occasional fine of Rs. 5 or Rs. 6. We have recently asked the Judicial Department to help us in this matter and you, in other provinces, may desire to take similar action. We have requested that a letter should be issued by Hon'ble Member, Judicial, to all Magistrates pointing out that fines for overloading buses or lorries should be such that if the culprit is caught once in three trips the fine should be sufficient to cover the total that he will have obtained from his overloading, *i.e.*, if he is making an excess Rs. 20 a trip by overloading the fine should not be less than Rs. 60. If this suggestion could be brought into practice all over India it would help matters considerably.

Another point I note with considerable sorrow that a 1½ inch tar-carpet has failed in Delhi. No explanation has been given so I trust the author of the paper will give us further details.

Col. G. E. Sopwith.—Mr. President and Gentlemen, I had not intended to speak on this paper. I refer to the paper by Mr. H. P. Sinha and Mr. A. M. Abbasi. As the authors are not here I intended and still intend to correspond with them because I do not quite understand about the alleged failure of the 1½" carpet. I have looked up the number referred to in the original paper by Mr. Dean read at the Congress last year and I find that it refers to 4 miles on the Karnal Road. I see that the economic life of the carpet is stated on another page to be one year. I

*This has been corrected to 1 place of decimal in the statements as reproduced in the proceedings.

confess that I am quite unable to understand this. As regards the Karnal Road although it is sealed with a material other than Tar the carpet itself, which was done about 2½ years ago, is still in excellent condition carrying a very considerable traffic. I went over it about 2 months ago and saw no signs of any failure.

As regards the 2½" carpet on the old Rohtak Road the delegates last year had the opportunity of seeing that the road had partially failed and I explained at the time that there were errors in the method of construction which caused partial failure almost immediately. A subsequent length of 2½" carpet which was laid under more satisfactory conditions and methods of construction had not failed up till the 19th of November 1935, *i.e.*, 14 months after it had been laid. This length is also on the Old Rohtak Road.

Mr. N. Nageswara Aiyar.—In studying the traffic statistics, the number of vehicles or the total tonnage per day or per hour is assumed as the basis for road design. The damage done to roads is not so much caused by the average load as by some of the heavy loads. Supposing there is one vehicle with a load of 6 tons or 7 tons, that, perhaps, does more damage on that particular road than 100 vehicles weighing only 1 to 2 tons each. In taking traffic statistics, we have necessarily to take not merely the total number of vehicles or the average weight of these vehicles but the maximum load on each vehicle that travels on the road. Therefore, necessarily, we have to give instructions to note the load on each vehicle. This is necessary only in the case of vehicles which are over 2 or 2½ tons. In order to give economic life to the road, it will be desirable to restrict the total weight of any vehicle that might use that road, depending on the surface.

Coming to bullock carts, so far as Madras is concerned the maximum weight which a loaded cart carries is only about 1 to 1¼ tons. Rarely do we find more than ¾ ton being carried in Madras and the tyres themselves are about 2 to 2½ inches wide and the diameter of the wheel varies between 5 and 6 feet the average being 5½ feet. This, in the case of average roads, has a tread on the road much more than what is given by wheels of 3 ft. or 3½ feet in diameter. We find on page 39 of the last paragraph of paper No. 15 that "for exclusive bullock cart traffic a cement concrete road can stand only upto about 100 vehicles per yard width of road". But I know that in the South Arcot District, in a place called Nellikuppam, just in front of the Sugar factory, a cement macadam road was laid in 1930. The total depth is 4 inches. Although it has been in use for about 5 years, I am told that there is not the slightest wear and it is as good as when it was laid. The traffic intensity there is one of the heaviest. The total number of bullock carts in the season, *i.e.*, from January to April is 1,800 per day. Yet the road has not shown the slightest damage except at certain joints which was later on filled up with some bituminous composition. The road has remained intact and there is not the slightest amount of wear.

Rai Bahadur Chuttan Lal.—Under the heading "Effect of iron-tyred vehicles on road surface", the authors of paper No. 15 have attempted to determine the pressure of iron tyres on road surface under actual traffic conditions and a pressure of over 4,000 pounds per square inch under the tyre of a loaded bullock cart has been calculated, neglecting the stresses due to impact. The authors consider that as the stresses produced are far in excess of the allowable compressive strength of concrete, a cement concrete road begins to show early signs of deterioration under

heavy bullock traffic. In support of this statement they cite the instance of mile 2 of the Delhi-Rohtak Road, the outline of the surface of which was obtained a year after its construction by means of a profilograph. This graph showed depressions of as much as $\frac{1}{4}$ inch and these depressions have been assumed to represent the tracking produced on the road surface by the iron tyres.

The first question that arises in this connexion is whether any graph of the road surface was taken or not when the concrete road was opened to traffic. If not, obviously no conclusions can be drawn from the observations of the depressions recorded a year later. There is nothing to show in the paper that the depressions were not defects in the original construction. It seems to me inconceivable that concrete road, if properly made, should wear under the load described in this paper to the extent of $\frac{1}{4}''$ in less than a year. In the United Provinces we have perhaps the largest milage of concrete roads in India and at this rate of wear some of the roads should have been rutted by now. Actual observation shows that even after 7 or 8 years of use—which the authors assume as the economic life of a concrete road—the wear is almost negligible, although the traffic on some of the concrete roads in the United Provinces is greater in volume and intensity than that recorded for the Rohtak Road.

The second question I ask is whether there is any evidence to show that the wear of $\frac{1}{4}$ inch on the road surface,—assuming for the moment that the surface has worn as stated, is due chiefly to the high compressive stresses under the iron tyres of the carts and not to other causes. Some light on the subject will be thrown by cutting 6 inch cylinders from the concrete slabs which have shown intense wear and testing them not only for compression but for their resistance to abrasion. But perhaps a drilling machine is not available for this purpose. The authors apparently assume that the cement concrete road has not stood the stress of traffic because a stress of over 4,000 pounds per square inch is far in excess of the compressive strength of concrete. This is rather vague, as strength is not an invariable quantity but increases with age. With sound materials and correct water-cement ratio, the compressive strength of concrete at one year's age will be much more than 4,000 pounds per square inch, perhaps more than 8,000 pounds per square inch. That compressive stresses have a bearing on the life and the wear of the road surface cannot be denied. But there seems to be some misapprehension on the subject. The specified compressive strength of cement concrete is based on tests of 6 inch cubes at 28 days subjected on two parallel faces to a uniform pressure and the ultimate compressive strength is determined by the load under which they fail by shear. Granular materials like cement concrete and brick generally fail in compression by shearing off triangular or wedge-shaped pieces at the ends, leaving a pyramid or wedge at the centre. When, therefore, we say that a concrete block under compression fails, we do not mean that it crushes into dust. The most widely used theory—the theory of maximum stress—is that a material will fail under any kind of stress when the maximum intensity of stresses reaches a definite limit, termed the ultimate, but inasmuch as there are cases, where no compression, however great, would produce failure, the theory is not applied to compression. If a round ball of cement concrete or a six inch cement concrete cube be exposed to a uniform hydrostatic pressure of say 15,000 pounds per square inch, over its entire surface, it will not break. Further, the same compressive intensity of stress over the face of a cement concrete cube would produce a

different result according to the area of surface to which it is applied. Thus the same intensity applied to a block over a part of its surface has very different effects from a compressive stress of the same intensity applied over entire surface. The point I wish to emphasize is that compressive stresses on the surface of a cement concrete road due to the iron tyres of a bullock cart should not be judged in the light of results of tests on small cubes of cement concrete 28 days in age. A 6 inch cube of cement concrete by itself is quite a different thing from a cube of the same size when it forms an integral part of a roadway concrete slab. If a 6 inch cube is by some means prevented from shearing diagonally or vertically, it can be subjected to a load of far greater intensity than would be safely borne by it without side restraint. It is a common knowledge that concrete columns reinforced spirally have a higher resistance because lateral deformation is prevented by steel. A resistance of about 13,000 pounds per square inch has been attained on the hooped core. For large reinforced concrete bridges on the continent in Europe, stresses exceeding 13,000 pounds per square inch calculated upon the cross-sectional area of concrete alone, have been employed with complete success, this being greater than the specified crushing strength of the concrete employed (see Scott's Reinforced Concrete Bridges). Cement concrete is capable of withstanding these high compressive stresses because of laterial reinforcement. In the same way the small portion of a cement concrete under the wheel of a bullock cart is prevented from shearing by the surrounding concrete and the firm base below. If the base over which the concrete slab is bedded settles, due to defective drainage or other causes, distribution of concentrated load over a larger area takes place in the first instance, as borne out by the experiments on slabs but cracks should in such cases, be expected. As another illustration having a bearing on this subject consider a 6 inch cube of ordinary water-bound road. This cube will not only shear but almost break into places under the load of a bullock cart, but the strength of a water-bound road should not be judged on the basis of the strength of such a cube. This cube when it forms part of a roadway will bear the load of a cart without breaking.

The third point I make is that if the compressive stress is the determining factor in the selection of a suitable type of road, as it ought to be, *if the usual working compressive stress on concrete is not to be exceeded* the selection should depend mainly on the maximum unit load it is likely to carry and not on the volume of traffic. The volume needs consideration in so far as it influences the width and the ultimate life of a road but not its strength as regards load-bearing capacity. Fatigue caused by repetition of loads carried by bullock cart is not a serious factor in the problem and, broadly speaking, it may be said that if the road is to break under the iron-tyred wheel of a heavily loaded bullock cart, the question of the volume of traffic does not arise. Yet the authors in their paper say that a cement concrete road can stand the traffic of only about 100 bullock carts per yard width a day. In the United Provinces, a concrete road at Cawnpore has been standing satisfactorily a heavy traffic of 1,660 bullock carts a day, for over 7 years. This question of the suitability of a cement concrete road to carry heavy traffic of iron tyres is of very great importance to us in the United Provinces and in the light of our experience, we believe that of all the types of road surfaces we have so far tried, cement concrete road is the only one which has stood the strain of heavy bullock cart traffic.

Lastly, tables III and IV call for certain remarks. Presumably, the formula for annual road cost is based on the assumption that an annual sum is to be set aside to form a fund at 5 per cent. per annum which will replace the depreciated value of the capital, *i.e.*, Mc-Rc. If so, the value of 'P' should be $\frac{r}{(1+r)^{n}-1}$ and r. M_c should disappear altogether from the equation. In the case of concrete road referred to in table III an annual sum of Rs. 414·69 should be set aside for 8 years. The total sum to be paid is Rs. 395 × 8 + 396 = Rs. 3,556 an excess of Rs. 238.

The authors do not explain why the residual value R_c has been assumed to be half of the capital value in all cases. In the case of a painted road the residual value seems excessive and in the case of concrete road, too low.

The authors should also have given some indication as regards the nature of repairs which make up the upkeep cost of road surfaces as given in table IV.

Mr. Syed Arifuddin.—We have heard with great interest a great deal about the effect of iron tyres and rubber tyres on the roads. But there is one aspect which has so far not been discussed in any of the papers or by any of the delegates and I wish to place it before you for your consideration. From my experience, I can say that there are instances in which a road is spoiled under motor car traffic sooner than under cart traffic on account of corrugations which are set up in the road surface under the effect of impact. For instance there is a road connecting one of the suburbs of Hyderabad called Begampett to Secunderabad a distance of about a mile and a half. There is very little cart traffic on this road; but motor car traffic has developed a great deal lately. Till about three years ago, it was only a gravel road. I found within six months of putting a new surface, considerable corrugations were formed, so much so that it would become very inconvenient for a motorist to drive over it. We thought that the solution of this trouble would be to convert the gravel into a water-bound macadam road. But within 9 months the water-bound macadam road also developed corrugations and we found it necessary to re-surface it the very next year. When I excavated the metal portion, I found that the thickness of metal had not altered very much and yet the corrugations were there.

These corrugations are said to be caused when large number of carts run over it, having the same wheel base length. In America same effect was noticed and is said that sometimes under special circumstances, traffic even on cement roads develop corrugations. This subject has drawn the attention of several eminent engineers in America and special theory has been evolved explaining the cause of corrugation.

I, therefore, consider it advisable that in future, whenever we take census of traffic on roads, it will be better to note down the length of the wheel base, so that we may know the conditions under which corrugations are formed. If no corrugations are noticed in some roads while others develop corrugations, it may be possible to test the theory of wheel base length.

Mr. K. G. Mitchell:—Mr. Laxminarayana Rao referred to the subject of bullock carts and various speakers have supported his contention that bullock carts are not so destructive as motor cars. We must get this

matter right. My opinion is that the two are not properly comparable. If you have both motor car and bullock cart traffic on a water-bound macadam road, the effect of the two combined will be quite different to that of each alone. It was shown many years ago in the Brunswick experiments that the combined effect of the two classes is very much greater than that of either taken separately. I do not understand what precisely is meant by saying that the one is not so destructive as the other. On a metalled road prior to the advent of the motor traffic, a certain amount of initial crushing of the surface took place and the surface was then protected by a layer of crushed metal and dust so that further damage was arrested to some extent. Motor traffic disturbs that layer and a lot of dust and fines are removed exposing the metal and crushing of the latter by the bullock cart traffic continues. Conversely there are light types of surfacing that are very little worn by motor traffic but are quickly destroyed by bullock carts. When we attempt to devise a dual purpose road by some bituminous surfacing of water-bound macadam, bullock carts are found to be far more destructive of that surface than rubber tyred motor traffic.

You may remember some years ago we published in the "Indian Roads"* a statement of the loads imposed on roads in different provinces by bullock carts. With the exception of Assam and Burma the load varied from 1,000 to 1,800 lbs. per inch width of tyre. We compare these with the Regulations in England in the days when iron tyred vehicles were in use and it appeared that in those days the maximum load allowed on water-bound macadam roads was about 600 lbs. per inch width of tyre. The loads in India are thus two or three times as great, and if you consider ill shaped tyres the destructive effect on our roads must be admitted to be very great.

I think that we ought to be definite and avoid loose generalities. I do not think any one can say that one sort of traffic is "more destructive" than another. It is the combination of the two on waterbound macadam roads that is destructive. No one in India as far as I know has made any precise measurements of the actual damage caused by the different vehicles separately and mixed. Any way the proof of the contention that the bullock cart is more destructive is the comparative ease with which surfaces can be provided to carry motor transport and the great difficulty in providing anything reasonably inexpensive to carry both.

Mr. R. L. Sondhi:—First of all I must thank all those delegates who have very kindly offered criticism on my paper as well as on the paper of Messrs. Sinha and Abbasi. As regards the questions raised about the latter Paper as stated in my introductory remarks, I will communicate these to the authors, as I myself do not agree with most of the conclusions arrived at by them, particularly as regards the wear of cement concrete roads. As a matter of fact, as organising Secretary, on receiving this paper, I raised similar objections and as a result of that arrangements have already been made that "profiles" are taken regularly and we hope that at the next session we will be able to inform you about the result of subsequent examination of the concrete surface.

As regards the remarks offered on my paper, practically all the questions that have been raised have been answered in the remarks made by Dewan Bahadur N. N. Ayyangar and Mr. K. G. Mitchell. Still I would like to say a few words.

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* "Indian Roads" No. IV, March 1933, Page 24.

Mr. Lakshminarayana Rao referred to para. 17 of my paper where I have dealt about certain collateral studies.

This work was really entrusted to the Executive Engineer, Provincial Division, Central P. W. D., Delhi, and was actually in the charge of Mr. Abbasi, the Sub-Divisional Officer. As a result of his studies (Paras. 6 to 8 of paper No. 15) this figure of 4,000 is arrived at by Mr. Abbasi and is based on the width of the tyres as shown in Table 1, at pages 32 and 33 of that paper. We have got the original impressions of the wheels here and they are available for inspection at the Congress-hall. On receipt of their paper I suggested it to Messrs. Sinha and Abbasi that they might get similar impressions recorded with a newly made cart wheel; because, after some use, wheels probably wear in a different manner. As a matter of fact, there may be only a certain proportion of the width of tyres that might be coming as an impression. Therefore, if we had compared these impressions with the impressions of the newly made cart wheel, probably, the results would be more instructive.

As regards Mr. Hughe's remarks, a reference to para. 6 of my paper will show that it is already decided to follow the main survey by test counts at certain periods of the day and the week for the remaining six months in order to arrive at seasonal variations. He quite rightly says that hourly, monthly, seasonal and yearly variations should be taken into account. The discussion of these details will probably form the basis of a paper next year, if possible. Because, if you will kindly refer to page 15 of my paper, in the first column of the form I have stated:

> "If desirable to obtain particulars of diurnal fluctuations, the time may be noted here every three hours and a line ruled across",

and in the original data that has been collected in the field, we have got the figures for not only the season, but for every hour of the 24 hours of each day of the six months. Our traffic data will give all the hourly total traffic that converges into Delhi from the main arterial roads that come into it. Later on, during the next six months, we have collected data on each of these roads for census points at the boundary of the Delhi Province and at different places where important roads go out of these roads or join these roads, so that we are able to find out the actual traffic between different census or subsidiary census stations separately. Probably, next year we will be able to give figures of what the traffic flow there is on this whole trunk system of roads. Having got for the first six months' actual counts of all kinds of traffic, and knowing as a matter of fact the load of every vehicle, whether it was a bullock cart, motor car, or a motor lorry, 'maximum' individual load for each kind of vehicle is available for the recorded field-data. The present table gives only averages. After further examining the field-data, we will be able to find out how many 'maximum-loaded' different kinds of vehicles passed over the roads. We are actually observing these experimental surfaces and keeping a quarterly note of their conditions and trying to get from the Central Public Works Department, the actual maintenance cost that they are incurring after the first surface was laid. With the information so derived, for a long period, it should be possible to arrive at the economics of these surfaces. It is an intricate subject, and in arriving at final conclusion we will benefit by the suggestions made by the various speakers who have offered remarks on my paper. We will be able, after further examination of field data to find out some sort of formula which will give us the proportion of the heavily-loaded cart to the ordinarily loaded cart

and the empty cart and their relative effect on the road surfaces. This is really a vexed subject and, probably, with proposed detailed examinations we will be able to give you more information in the next year's paper. After all, these averages give us something to go on with and further refinements are reserved for later study.

As regards Mr. Lakshminarayana Rao's criticism I have to explain that the area of contact of wheel as worked out by him is the same worked out by Messrs. Sinha and Abbasi in Table 1, Column 11 of paper No. 15. If we conduct similar experiments with truly turned cart-wheels we will perhaps be able to arrive at the coefficient which should be adopted and we will then perhaps be able to find out actual intensity due to wheels that are in use.

The next point is that Mr. Lakshminarayana Rao objects to the iron-tyred carts being dubbed as most destructive. As Mr. Mitchell has explained, both motor cars and bullock carts to some extent contribute to road destruction in a certain way, if they are working separately. But when they are working together, the effect is really more because the fillings rasped out by the bullock carts are sucked out by the motor tyres. I have already explained in the paper that the traffic intesity figure per yard is not really intended to be used. The same is the conclusion arrived at by the Technical Sub-Committee, as will be seen from their report, circulated today. Absolute total traffic is really the figure which affects our road design, and, therefore, Mr. Lakshminarayana Rao's question does not arise.

As regards his reference to frictional resistance, the resistance to traction is no doubt directly proportional to pressure and on solid unyielding surfaces is independent of the width of tire; but on compressible surfaces it decreases as the width of tire increases. Further, on uniformly smooth surfaces the resistance is independent of the speed.

Therefore in the case of modern surfaces wide pneumatic tyres of lorries are less destructive than narrow iron tyres of bullock carts.

As regards Mr. Reidshaw's remarks that the fines imposed should be in proportion to the income derived by the man who disobeys the rule regarding the load, I have already myself suggested, in my paper, the strict enforcement of more rigid motor vehicle rules. I hope, even more stringent measures than recommended by Mr. Reidshaw will be taken and our roads will not be allowed to be damaged by the over-loaded vehicles in the way they are being done now.

Mr. Nageswara Aiyar has pointed out that bullock carts in Madras do not carry more than three-fourths of a ton. From the actual calculations made by us in N. India, corresponding load works out to 1·6 tons, as noted in the different statements in the paper. Perhaps our bullocks are much stronger than those in Southern India and they carry heavier weight! The fact that Punjab are having quite good roads and are catering for the sturdy bullocks which are carrying very heavy loads is very creditable to those who are maintaining those roads.

As regards Mr. Hughes' remarks that working to two places of decimals in the statements in my paper was an unnecessary refinement. These can well be omitted. The more latitude we allow in making calculations of roads statistics simpler the better; as there are bound to be lot of approximations in the collection of road-census data, etc. So we will round the figures where possible, in the final publication.

Mr. Arifuddin's suggestion regarding wheel bases of motor cars, is worth pursuing. We really have noted the registered number, chassis number, the maker's specification and everything relating to the vehicle, including the wheel-base. I think we have taken sufficient precaution in the matter and the field-data collected in this census is comprehensive enough to furnish enough information for further studies.

Chairman:—We have had a very interesting and useful discussion on this important subject which should form a basis for future investigations that are being carried on in the Central Public Works Department at Delhi. You will join me now in passing a very hearty vote of thanks to the authors of these three interesting and useful papers.

CORRESPONDENCE.

I.

Replies by the authors (Messrs. H. P. Sinha and M. A. Abbasi) to criticisms on their paper No. 15.

1. *Reply to criticism made by Rai Bahadur Chuttan Lal.*

We are grateful for the criticism from Rai Bahadur Chuttan Lal, as this affords us an opportunity to correct any misapprehensions or mistakes that may have arisen on circulation of this paper. At the outset we would like to make it clear that the scope of this paper was restricted to the effects that the traffic of iron tyred vehicles produce on the life of roads. Experiments were, therefore, performed on various kinds of road surfaces that the authors had the opportunity to meet with, and the results along with the conclusions were put together in this paper. Concrete road surface naturally was one of the subjects of the experiment and received its share of attention. It was however never the attempt to investigate into the ways in which the failures of a road surface can occur. This subject in itself is so wide that it could not be dealt with justice in such a short paper. There appears to be a misapprehension on the nature of wear attributed to concrete road in this paper. The wear has been taken by the readers as a regular rutting on road surface. This is not the case. The wear is exhibited only locally at a number of places which cannot be taken as constructional defects.

2. No profiles were taken by means of profilograph immediately after constructing the road as the instrument was not available then. A profile taken at that time would have been, however, of little use as it could not be determined where the wearing spots would appear in future. It will, however, be now possible to watch further developments of these spots with the course of time. That the wearing spots are not dips left at the time of construction, can be judged by the nature of surface which shows distinct signs of disintegration. These local spots are bound to increase both in number and size and thus spoil the road. A close inspection of the roads made recently has revealed that such points of wear can be noticed in 15 to 20 per cent. of the bays of the two concrete roads in Delhi, *viz.*, the Rohtak Road and the Grand Trunk Road to Ghaziabad. Each bay is about 33 feet long.

3. As mentioned before, the discussion on the ways of failure was outside the scope of this paper, but it would now be worthwhile to go into this question for concrete road since the subject has been opened. It has not been mentioned at any place in the paper that the wear on concrete surface is caused by pure *static* compressive stress. *In fact* the wear is the result of the grinding action of the iron tyres against the road surface at the weak spots which cannot be eliminated even under

the most careful construction. The grinding action or abrasion of the surface, being the direct consequence of compression increases with the intensity of load as well as with the volume of traffic. It is, therefore, not correct to ignore the volume as has been arrived at in para. 4 of the criticism. The authors did not mention that the concrete road "has not stood the stress of traffic because a stress of over 4,000 pounds per square inch is far in excess of the compressive strength of concrete". In para. 10 of the paper it is said that if the effects of impact, etc., were taken into account the total stresses produced would be much greater and occasionally in excess of the compression strength of cement concrete. That the stress occasionally reaches a figure above the ordinary compression strength of concrete (without allowing even for the usual factor of safety) will be showed shortly. But the authors' statement of early deterioration of cement concrete road under heavy bullock cart traffic should not be taken to mean that the failure occurs instantaneously by pure compressive stress as is the case in test blocks of concrete. The three main reasons of failure appear to be (1) Grinding action, (2) Direct action of load on parts of concrete where voids may have been accidentally left. (3) Cutting action of the wheels. Coming to the question of the max stress that may at times act on the concrete surface, the value of this stress is doubled due to the effect of impact. Besides the impact there is always the twisting action of the wheel which tend to cut into the surface. The results of test of the concrete cylinders 4" dia. & 8" long, made from the material actually used in these roads, show a compressive strength of nearly 4,000 lbs. Sq" after 28 days. Such a concrete would not attain a strength of 8,000 lbs. Sq" or over after a lapse of one year. An increase of about 10 per cent. only can be normally expected. It is, therefore, quite possible to obtain a stress much above the compressive strength of concrete as observed in test blocks. No doubt the direct effect of compressive stress cannot be compared with that on a test block owing to the entire mass of road slab working as a whole against the point load under the tyres. It may, however, be pointed out that a concrete road slab has unsupported faces at the edges and joints and can, therefore, behave to some extent in the manner described for the 6" test cube in the criticism.

4. The effect of volume has already been dealt with in para. 3.

5. It is regretted that due to misprints* the formula of road cost was unintelligible. It runs as follows:—

If Mc = Construction cost of a surface.
Rc = Residue value.
Mu = Upkeep cost.
n = Number of years of economic life.
r = interests on Re. 1 in one year.

$$\text{then } p = \frac{r}{(1+r)\left\{(1+r)^n - 1\right\}}$$

Where p is defined as the unit reserve which implies that an amount equal to "p" if set aside every year would accrue to Re. 1 in n years at a compound interest of "r".

All the results incorporated in the tables were calculated on the basis of the above formula and not on the one that has appeared in the printed paper by mistake.*

The only difference between this Formula and the formula arrived at by Rai Bahadur Chuttan Lal lies in the factor (1+r) appearing in the denominator in the former case in place of (1) in the latter. This is due

* Corrected in the text of the paper as appearing in these proceedings.

to the reason that we have considered the deposit of the last year, also to earn the interest for one year which actually will be the case if the amount is set aside at the beginning of every financial year. The term r × Mc cannot be deleted, as this represents the interest on the capital cost.

The equation of Road cost will therefore stand as before, *i.e.*—

Road cost = (Mc-Rc) × p + Mu + r. Mc.

The residual values have been fixed approximately in the absence of any hard and fast rule.

The cost of 7′-5″-7″ road will generally work to about Rs. 40 per 100 square feet in Delhi. The residual value will be equivalent to the value of an under bed and will be in fact less than Rs. 20 per 100 square feet. In bituminous road surfaces the bitumen can be recovered from the broken road and made use of directly on unimportant surfaces as foot-paths, or on roads after refining.

It is reckoned that about 50 per cent. of the value can thus be recovered in this way.

The figures of the upkeep cost have been taken from the actual expenditure incurred on the Provincial Roads in Delhi.

2. *Reply to criticism made by Mr. G. Reidshaw.*

The point raised by Mr. G. Reidshaw is outside the scope of our paper. Our aim has not been to investigate the causes of failure of a treatment but to determine its total road cost by the life it has under similar conditions of traffic so that a comparison can be made of the different treatments.

As, however, this question of premature failure of certain treatments in Delhi Province has attracted attention of many of the delegates of the Bangalore Roads Congress, the authors are glad to offer the following explanation for the same.

The two important factors for the stability of a road treatment are (1) the quality of the rock from which the mineral aggregate is obtained and (2) the structure and function of the material used as binder.

The results of the petrological examination and the mechanical tests of the Delhi rocks which were carried out at the Government Test House, Alipur, Calcutta, showed that the rock was hard and its wearing quality good, both during the dry weather and the rain, but that it was rather brittle and crushed under a heavy load. Any treatment, therefore, which did not include a binder that possessed good adhesive qualities to the mineral aggregates would fail with this grade of stone metal.

Tar as compared with bitumen has a higher surface tension; its wetting quality is poor and its capacity to hold the stone grit together is likewise low.

The investigations on surface tensions carried out by Dr. F. J. Nellensteyn, Director of the State Laboratories, Delft, Holland, show that the stability of the whole system of bitumens or tars depends on the surface tension of the oily medium to which the adhesion of these materials to the other substances, such as different mineral aggregates, is due. The lower the surface tension, the better the wetting quality that can be expected.

The failure of 1½ inch and 2½ inch tar carpets on provincial roads within one year of their construction is attributed to the above factors. Within a few months of their construction it was observed that the tar had lost its stickiness and each individual stone was now held more by friction than by cohesion of the binder. With the heavy load coming on them these individual stones were in the first stage crushed or fractured and the surface developed fine hair cracks round them. In the second stage these crushed

stones were carried away by the faster moving traffic and the process of failure was completed. The carpet was now in danger of being scooped out totally and therefore it was decided to lay immediately a wearing surface over it. A surface treatment with hot bitumen and ½″ stone grit was applied to the 1½″ carpet in the major portion and has proved effective. A small portion was, however, given a seal coat with tar, but could not check the tendency of disintegration. No seal coat was applied to 1½″ carpets at the time of construction as the firms' specification did not require it. In the case of 2½″ carpet (new length), however, a seal coat was applied a few days after its laying. The carpet even then showed movement and fine hair cracks round individual stones. The condition of the road was noticed by Col. Sopwith, General Manager, Shalimar Tar Products, sometime in April or May 1935, who advised brushing down the surface with No. I tar and repainting it with No. II tar using about 14 lbs. of the former and 20 lbs. of the latter. This proved effective for sometime but many patches have again been formed and the carpet has failed even after an application of 34 lbs. of tar as surface coat.

3. *Reply to criticism made by Mr. N. Nageswara Aiyar.*

The points raised by Mr. N. Nageswara Aiyar are (1) the basis of road design being assumed the number of vehicles or the total tonnage per day or per hour carried by a road does not satisfy the condition that heavier individual vehicles cause more damage to a road than light vehicles (2) the conclusion that a cement concrete can stand up to 100 bullock carts per yard width of road is not borne out by the experience of a Madras road which carries a traffic of 1800 bullock carts per day for 4 months in a year. The load carried by each individual cart is stated to vary between 1 to 1½ tons and width of tyres is from 2 to 2½ inches. The pressure intensity which is exercised by a vehicle on the road surface has no doubt to be taken into consideration in a road design.

For the purpose of comparison, however, the basic unit of load per yard width in 24 hours has been adopted by us. Our remarks in respect of the cement concrete road standing up to an exclusive bullock cart traffic of 100 carts per yard width refer to this Province only for which table V referred to is prepared. The load of a four wheeler bullock cart varies between 2 to 3 tons. Obviously, therefore, when the conditions of traffic are not the same in Madras, these remarks cannot be applicable to roads in that Province.

II. *Points raised and answered by correspondence on* PAPER NO. 15.

COL. G. E. SOPWITH.—In table 4 on page 37 of the paper it is stated that item 5, Tar Carpet 1½ inches, failed in the first year and the same remark is made against item 6, Tar Carpet 2½ inches. On referring to the original paper by Mr. Dean, it appears that item 5 refers to the 3½ miles on the Karnal Road. These miles were laid but not sealed in the first instance as at that time I did not consider it essential to seal almost immediately after laying the carpet. Owing however to the brittleness of the stone a tendency showed itself for the stone in a few places to crack under traffic and I asked in consequence that a seal coat should then be put on. This however was only done with Tar for a few yards and the quantity of tar used was definitely insufficient and less than that recommended by me. Later on the rest of the carpet was sealed with bitumen and the carpet in November 1935 was still in excellent condition after 3 years. I do not understand therefore why it was stated to have failed in the first year unless it be

that the interpretation of failure was that the cost of a seal coat had to be incurred. If this is the reason for the statement I suggest that it is an incorrect one as, according to Shalimar Tar specification, the seal coat is an integral part of a carpet and the only question that arises is whether it should be applied shortly after consolidation of the main body or at a later date. It is true that in our pamphlet it was stated that a seal coat was unnecessary though a painting coat 2 to 12 months after consolidation was an advantage but at the time when the carpet was laid it had already been discovered that the seal coat for this particular specification was essential and this was brought specifically to the notice of the Superintending and Executive Engineers as well as of Mr. Abbassi who was in direct charge of the work.

As regards the 2½ inches carpet the remark applies presumably to the original length laid — from the bridge under the railway for about 2 furlongs. As explained at the time to the delegates of the Indian Roads Congress who visited Delhi in December 1934 various mistakes occurred during actual construction, and in addition patching of the road which contained numerous pot-holes was carried out and the carpet laid on it before proper consolidation of these patches by traffic had occurred. In consequence of this the carpet definitely failed in several places very soon after consolidation. I actually used this as an illustration of the necessity of exact construction in accordance with the specification, and a new length of 2½" carpet was laid nearer to Kishenganj Station in 1935. This carpet was laid with much greater care and when I last saw it in November 1935 it was standing up excellently to the traffic.

I would not have raised this point at all had it not been for the actual form of the entries made in Table 4, which suggests that Tar carpets generally are a failure—a fact which is proved otherwise by the many miles of successful Tar carpets which have been constructed and have stood up to heavy traffic over long periods in such varying climates as Bengal, Madras, The Punjab and the Peshawar district. This paper which will be read by many who have not had an opportunity of seeing existing Tar carpets might well lead them to suppose that a Tar carpet is a thing to be avoided.

Reply to criticism made by Col. Sopwith.

We regret that we cannot accept Col. Sopwith's contentions. The 1½ inch tar carpet was laid on Karnal Road as he has mentioned. In accordance with the specifications of the firm, it was not sealed because a seal coat was said to be unnecessary, the first painting of the old surface being supposed to act as sealing (see specification No. 6). When the carpet began to give indications of disintegration, a seal coat of tar was applied in a length of half a furlong at a rate of 14 pounds per hundred square feet, remaining portion was given a seal coat with bitumen at 30 pounds per hundred square feet. The carpet with the seal coat of tar failed again and that with the bitumen is standing. The success cannot, therefore, be ascribed to tar, but to bitumen. As regards 2½ inch carpet, the reason for the failure cannot be attributed to the sub-grade when a similar treatment of 2½ inch Shelcrete is standing in the adjacent reach of the same road, having the same kind of base and constructed at about the same time. The portion of 2½ inch carpet mentioned by Col. Sopwith to be "standing up excellently" in November 1935 is no longer in that state. That surface had been lightly brushed with 14 pounds of tar No. 1 and then given a seal coat with 20 pounds of tar No. 2 in May 1935, after 6 months of life and therefore presented a good appearance in November 1935.

First day, Thursday, January 9th, 1936—contd.

GROUP 2—ECONOMICAL MAINTENANCE AND IMPROVEMENT OF MACADAM, SURFACE TREATMENT AND CARPETS:

CHAIRMAN—MR. H. HUGHES.

Chairman:—I now call upon Mr. S. Bashiram to introduce his paper.

The following paper was taken as read:—

Paper No. 17.

ECONOMICS OF ROAD MAINTENANCE

BY

S. BASHIRAM, I.S.E., SUPERINTENDING ENGINEER, PUNJAB, P. W. D.

With the rapid and increasing development in road traffic that commenced about the year 1925 and the advent of the now ubiquitous motor bus and the lorry, Indian roads have been called upon to meet strains they were not built for. The anxieties of the road engineers responsible for their upkeep have also been augmented by the fact that funds available for maintenance have been and continue to be meagre, so much so that several Provincial Governments have been compelled temporarily to divert to maintenance a substantial moiety of their receipts from the Central Road Fund, which was and is solely intended for new construction. To add further to their embarrassments there has been by stress of circumstances forced upon them within recent years an appreciable increase in their responsibilities with respect to roads. Metalled and unmetalled lengths have increased and standards have risen simultaneously. Not only has the road engineer therefore been called upon to make a rupee go to the furthermost limit but so to alter his existing specifications that they not only meet present conditions but will also afford him breathing time to evolve others that may be more suitable to the needs of the future.

2. The old water bound macadam is now rapidly being superseded by other surfaces involving the use mainly of tar and bitumen and to a very limited extent of cement. The problem that faces the road engineer at the present moment is to eke out the funds at his disposal in order to preserve from deterioration the longest length possible of the existing roads in his charge and to devise the cheapest specifications that will meet the various conditions of traffic that may be expected to be met with in the near future. This problem is being solved, at least in the Punjab, by painting as rapidly as funds will allow, the existing surface mainly with tar; and meanwhile carrying out experiments with varying specifications to suit different types and intensities of traffic. Further in order to get the most beneficial results from tarring (and bitumen treatment is included in this term) the initial and succeeding coats must be given in a systematic and not haphazard manner as heretofore. This postulates a carefully tabulated record of all work done in each mile of a road and of the traffic it carries.

3. In the days of water bound macadam one did not worry about the volume of traffic a road carried. No traffic census was ever attempted and the surface was renewed when it became necessary to do so. A simple record was kept of the financial years during which the renewals were effected. A note was sometimes given when stone was substituted for kankar but seldom was an attempt made to indicate even the quarry from which the former was obtained. Things are very complicated now. Mere appearance is no longer a guide as it generally was with water bound macadam and in the absence of aids obtainable from reliable and properly recorded data to help him in working out his maintenance programmes, the road engineer may be faced with a situation where the entire surface of his black roads is fast breaking up.

4. A study of the behaviour of Black Surfaces now in vogue must take into account:—

(*a*) the specifications employed—whether simple painting, grout, semi-grout, or any other;

(*b*) the nature of the under surface, *e.g.*, whether quartzite, sand stone or lime stone;

(*c*) the nature, quality and quantity of the binder;

(*d*) whether river worn or hand crushed grit has been used or otherwise;

(*e*) the humidity and temperature and therefore the season during which treatment is given;

(*f*) the volume and nature of traffic carried, and a host of other factors. It is further important, if full benefit is to be obtained from tar applications, that up to a point, even though the road surface is standing well up to traffic, they should follow each other at certain though unequal intervals. In the absence of suitable data readily available, it is difficult, if not impossible, for controlling officers to see that such applications are not being skipped over or given too frequently and the expenditure already incurred or proposed to be incurred thereby allowed practically to go to waste. Cases have come to the author's notice where the first application was allowed to serve for as long as two years and the second for two and a half years—a criminal waste of public funds revealing a complete ignorance of the very fundamentals of the uses of tar for roadwork. The first coat should not be allowed to dry out and must be covered over by another within six months to prevent excessive evaporation of the lighter oils. If this is not done the first coat is likely to peel off even though the subsequent coats are applied at proper intervals. The foundation work having thus disappeared further coats are rendered more or less valueless. Experience in the Punjab shows that the intervals should be six months between the first and the second, 12 months between the second and the third and 18 months between the third and subsequent coats. It is likely that the further intervals may be increased to 24 months each depending of course on the nature and volume of traffic.

5. If a careful record is available of the nature and volume of traffic on a road it should be possible, as a result of careful study of the foregoing data, to prescribe with some confidence the cheapest specification

that would meet its needs and by avoiding wasteful or at least extravagant expenditure to effect economies in maintenance. It should further be possible to frame in advance fairly reliable maintenance estimates for a number of years and thus forecast expenditure. With the financial commitments known it should be a simple matter to plan out programmes of development. It must be remembered that the milage of roads in a country is ultimately far more dependent on what funds it can afford, to meet recurring expenditure for the proper upkeep of its road communications, than on the sum it can invest on their initial construction. This consideration applies of course far more forcibly in the case of metalled than of the unmetalled roads.

6. The foregoing emphasises therefore the absolute necessity of reducing maintenance costs as far as possible and with a view to achieve this end it is essential to collect all relevant data in a scientific manner. Attention is now at long last being given to the technical aspects of the problem but the statistical side has so far not received that consideration which will enable the community to derive the maximum benefit from results obtained on the technical side. The object of this paper is to rectify in some measure this omission and to suggest lines along which this statistical data should be recorded in a set of road tables.

7. The following information about a road is considered necessary for its efficient maintenance:—

(a) The source and quantity of metal used in the wearing surface to which treatment is applied and the date of its consolidation. In new construction the same remark will apply to the foundations.
(b) The nature and quantity of the binder used.
(c) The nature and quantity of grit used with each application and whether it is river worn or hand or mechanically crushed.
(d) In the case of surface painting, the number of applications made.
(e) The time and life of each application.
(f) How each treatment has behaved.
(g) The amount and nature of average daily traffic, and
(h) The average annual maintenance cost per mile.

8. It is further desirable to compile for each year the following data for a road:—

(i) Total milage.
(ii) Treated milage (metalled),
(iii) Untreated milage (metalled),
(iv) Milage unmetalled.
(v) The number of miles on a road that have had one coat, two coats, three coats and more than three coats, separately for tar and bitumen.

9. In the set of tables that form an appendix to this paper an attempt has been made to compile the above information. A brief explanation is however necessary to explain how it should be tabulated.

SHEET No. 1. gives brief explanatory references.

SHEET No. 2 refers to any one road, covers a convenient period, say 10 years, and is self-explanatory. It gives for the road its name and location, the total treated and untreated metalled milage and the total unmetalled milage. It also gives the numbers of miles, separately for

tar and bitumen, that have had one, two, three and more surface applications. Columns have also been provided to show the number of miles which although not surface painted have been treated otherwise, *e.g.*, grouted or semi-grouted. The last column shows the average annual maintenance cost per mile and a comparison of these figures *inter se* will show whether any economies have been effected in maintenance costs as a result of change in specifications.

SHEET No. 3 deals with matters of technical interest and refers to a particular road. Miles are indicated on the top line by their numbers.

10. The first horizontal column shows the source from which the metal for the wearing coat was obtained, its quantity and the month and year of consolidation. A convenient symbol is given to the quarry from which the metal was obtained and this automatically gives the nature of the stone whether quartzite lime stone, sand stone or any other variety. Laboratory tests in a Deval or other machines regarding abrasion, toughness, resistance to crushing, etc., of the stone used will carry us a step further towards a scientific analysis and yield data of more than local application.

11. The second and subsequent horizontal columns show for each mile the year to which the entries relate and the months in which applications were made are shown by the three commonly accepted letters, *e.g.*, Jan. for January, Feb. for February and so on. Where two applications were given in the same year, as may well happen in the case of the initial and the second coat, the relevant column of the mile has been divided into two by a vertical line and the entry on the left refers to the initial coat and that to the right to the second coat.

12. In the Punjab, surface treatment did not become a general practice till about the year 1931 but, with the exception of very short lengths in and around Lahore, some odd miles were painted in the two or three preceding years. It would become cumbersome to have several sheets for each road with only one or two entries thereon. It is suggested therefore to start the diagrams commencing from the year 1931 and to enter therein any information prior to this year in the form of footnotes. A reference to the entry for mile 86 against the year 1931 on SHEET 3 of the Appendix will make this clear.

13. It is necessary to know how the various applications have stood up against traffic and the quantity of patch repair bajri required to maintain the surface till the next application is given is a fair index of this. This quantity in cubic feet is given in figures below the three letters indicating the months in which the application was given. Thus from SHEET 3 of the Appendix attached to this paper, we see that in mile 64, 122 cubic feet of bajri was used between September 1932 and January 1933 and 302 cubic feet between January 1933 and October 1934. In mile 63, two applications were given in the year 1934, one in January and the second in October. Twenty-five cubic feet of bajri was used between the first and second applications and 20 cubic feet between the second and the third in April 1935.

14. It will obviously be confusing if we enter on the same sheet the quantity and nature of the binder and the grit used with each application. The standard practice in the Punjab now is to use, for a mile 12 feet wide, 8 tons of tar No. 2 and 2,000 cubic feet of 1/8 to 3/4 inch gauge bajri for the first coat and 4 tons of tar and 1,200 cubic feet of

1/8 to 3/8 inch gauge bajri for the second and subsequent coats. Where any departure from this standard practice is made, the month of application is underlined in the diagram and the variation detailed on a sheet of Notes which follow SHEET No. 3. As a description of these variations may require several Notes sheets, these are numbered 3a, 3b, 3c and so on. This method of numbering them also gives a clue to the relevant sheet on which the miles they refer to appear and a reference to the latter gives particulars regarding other information about the miles entered thereon.

15. The source of the grit used in a particular stretch of the road is mainly governed by economic considerations and bajri is obtained from the nearest suitable quarry. This factor thus remains more or less constant for any particular stretch of a road and is indicated on the relevant SHEET No. 1 against the reference entry C(b) for SHEET No. 3. In the few cases where bajri is obtained from a different source the relevant *month* entry is also underlined and the deviation indicated on the Notes sheets.

16. In view of the standard practice of using tar only as a binder, some notation is required to show where bitumen or some other material has been used. The simple method of encircling the three *month* letters has been used to indicate this departure from the standard practice. As the types of the bitumen binder available for road purposes are numerous, and the quantity of both this binder and grit used have not been standardised it is necessary to carry such treatments on to the Notes sheets and therefore all bitumen applications should be encircled.

It is clear from the above that a reference should be made to notes in all cases where the months of applications have been either underlined or encircled.

17. One of the most important data required by the road engineer is that relating to the amount and nature of average daily traffic. In European countries this traffic consists almost entirely of pneumatic tyred motor vehicles and its intensity is indicated generally in tons per yard width of road. Conditions in India are very different. Bullock carts are the normal means of transport and they travel in batches in one another's wake along fairly well defined ruts. This being so, from the point of view of this traffic, the width of a road is immaterial. The intensity of traffic in India must therefore be measured in absolute terms for the entire width of the road and not per yard width. There is the further factor that the wheels of some bullock carts are shod with iron tyres while others are fitted with plane wooden tyres. Since the effect of the former in destroying a road surface is vastly greater than that of the latter, it is essential to classify them separately. In addition to the bullock cart there is also the motor traffic but as this is almost entirely pneumatic tyred, no separate cataloguing of the small car and the lorry is necessary. To have a complete picture therefore we want not only the total daily tonnage of traffic on a road section but also an analysis to show its composition, *viz.*, the number of bullock carts fitted with (a) iron, and (b) wooden tyres, and the total average daily number of motors. This traffic census is shown on SHEET No. 3 against each year of entry and the sections to which a set of these census figures relate are indicated by triangles. These sections should be most carefully determined if this information is to be of any value.

18. If the census figures are to be of any intelligent use there should be an indication on SHEET No. 3 of towns situated along, and other roads which take off or join, the particular road to which the diagram relates.

Towns are indicated by their names and the roads by vertical lines at suitable places on the thick top line along which the numbers of the various miles are entered. The entries on SHEET No. 3 referred to so far are of the nature of a permanent record. This sheet can however be made of more immediate use to the executive officers in charge of the road such as the executive engineer, the sub-divisional officer and the road inspector by providing a space for entries relating to any current year. This has been done by adding at the bottom of the sheet a column well below and independent of the main table. The system of making these entries should be the same as outlined above, but the predetermined programme should first be entered in pencil since any likely changes, and some are bound to become necessary in view of altering circumstances, can be made by erasing the old entries and filling in new ones. As the programme materialises, entries in ink take the place of pencil entries. Controlling officers can also keep in touch with any current year's work and easily ascertain by a reference to this sheet whether the programme is being carried out or not.

19. The number of sheets similar to SHEET No. 3 will depend on the number of miles on a particular road about which information is to be tabulated in one set of diagrams which it is presumed will relate to the entire length of a road or to that portion of it which lies in one district or sub-division.

20. The last sheet in the set follows more or less the lines on which SHEET No. 2 has been drawn up, but refers to more roads than one—the number of roads depending on the requirements of the case, *viz.*, whether the set is required say by the Executive Engineer or the Superintending Engineer. The form is self-explanatory.

21. So far we have considered only the statistical side of road maintenance, and we can now proceed to deduce therefrom the main object underlying this paper and which gives it its name, *viz.*, the economic of road maintenance with particular reference to proper control within reasonable limits of maintenance costs of metalled roads. A study of a sufficient number of sheets similar to SHEET No. 3 should enable us to say which type of surface, in ascending order of higher specification, gives, economically speaking, the cheapest road for 100, 150, 200, 250, bullock carts per day. The number of motor cars plying on a black surface road may for the time being be ignored for it is believed that up to a point it is the bullock cart alone, especially the iron tyred one, which is responsible for the destruction of the surface. It may further be possible to convince the legislature of the fact apparent to all road engineers that it is an economic proposition of major importance completely to warn the iron tyred bullock cart off its roads. A study of the traffic census figures will enable us to classify stretches of roads according to the intensity of destructive traffic that they carry and to specify suitable specification from a set of standard ones drawn up as the result of experience. It should further become possible to forecast with some accuracy the average maintenance cost year by year for a certain period of time and thus enable the controlling officers to effect better control when departures from anticipated figures attain proportions which may call for investigation. In short, the day may be hastened when the present transitional methods of road maintenance would become more scientific and economical rather than haphazard and in certain cases wasteful as now.

APPENDIX.

Sheet 1.

References to Sheet No. 2.

Information is here given regarding (1) the number of miles (A) treated with (i) tar and (ii) bitumen and in case of the former also the number of treatments they have received, *viz.*, one, two, three or more tar applications, and (B) still remaining untreated; (2) the average annual maintenance cost per mile in the district of the road named.

Note.—This form can easily be varied to show the above information (which may be for a division, circle or the whole Province) by roads as in *sheet 4* instead of by years.

References to Sheet No. 3 et seq.

A. Miles to which the entries relate.

B. Month and year when the wearing surface was last consolidated, and the quantity and source of stone metal used. The name of the quarry is indicated by an appropriate letter, *e.g.*, "J" indicates Jaijon quarry; "C", Chandigarh quarry; "L", Local stone; etc.

C. This gives for the CALENDAR year shown (*a*) the month during which the surface was treated, (*b*) the nature of treatment, (c) the quantity of bajri used for patch repair during any two successive treatments, and (*d*) the gross average daily tonnage of traffic passing over the ENTIRE road width as well as the number of various kinds of vehicles comprising it.

(*a*) The month is indicated by the usual three letters.

(*b*) For a $\frac{\text{first}}{\text{2nd or subsequent}}$ coat $\frac{2{,}000}{1{,}200}$ cubic feet of $\frac{\frac{1}{2}\text{ to }\frac{3}{4}\text{ inch}}{\frac{1}{8}\text{ to }\frac{3}{8}\text{ inch}}$ gauge—quarry bajri and $\frac{8}{4}$ tons of Shalimar Tar No. 2 have normally been used per 12 feet wide mile, *i.e.*, $\frac{250}{300}$ cubic feet per ton of tar for a $\frac{\text{first}}{\text{2nd or subsequent}}$ coat.

Note.—UNDERLINED months still indicate treatment with TAR but connote departures from the above practice,

ENCIRCLED months indicate bitumen treatment and also possible departure as regards quantity of binder and/or gauge and quantity of bajri used.

It is imperative therefore to refer to notes accompanying the diagram in each case where the month is either underlined or encircled.

(c) The quantity of bajri used for PATCH REPAIR work after a treatment gives information as to how the treatment has stood on the road. Figures under the months show the total quantity so used till next treatment. Where two treatments have been given in the same year, the appropriate column has been divided by a vertical line. The left half of column shows the month when the first treatment was given and the figures thereunder the quantity of bajri used till the second treatment. The right half of the column shows the month of the second treatment and the figures thereunder the quantity of bajri till the third treatment. The surface diagram has been prepared to show treatments from the year 1931 onwards. Some miles were however treated earlier and these treatments are mentioned in footnotes after giving a suitable indication in the relevant column opposite the first year in which the mile was treated during the period covered by the diagram.

(*d*) The black triangles mark the section to which the traffic census figures relate. The gross average daily tonnage is shown on the left of the oblique line and then follow in order the number of (i) IRON tyred bullock carts, (ii) WOODEN tyred bullock carts, and (iii) MOTOR vehicles of all description including lorries.

D. Blank spaces have been provided to fill in, on the same system as above, information regarding the programme of work intended during the year shown. The entries should first tentatively be made in pencil and as the programme materialises, they should, after corrections if necessary, be inked in.

Sheet 2.

__________ Division.

__________ Road   __________ Sub-division. / District.

Total Milage __________

	Year.	Treated milage (metalled).	Untreated milage (metalled).	Milage UNMETALLED.	Tarred Milage Details.							Average annual mainten-ance cost per mile in rupees.
					Tar.					Bitumen.		
					Surface Treated.				2 Treated otherwise.	Surface painted.	Treated otherwise.	
					1 coat.	2 coats.	3 coats.	Over 3 coats.				
1	1930-31											
2	1931-32											
3	1932-33											
4	1933-34											
5	1934-35											
6	1935-36											
7	1936-37											
8	1937-38											
9	1938-39											
10	1939-40											

1 page

Sheet 3-A.

NOTES.

Ambala-Tibet Road. Kalka-Simla Section.	Simla District.	No. 2 Simla provincial sub-division.

1931.

Nil.

1932.

Nil.

1933.

Mile 42 was renewed with premixed metal (2 per cent. tar in metal) painted with spramex in May 1933 and again painted with tar and mexphalt in December 1933.

Mile 44 was renewed like mile 42. Painted with tar and mexphalt in December 1933.

1934.

Miles 42 and 44 were repainted with ordinary coat of tar over a coat of tar and mexphalt.

Miles 45 and 47 were renewed with tar grouting in March 1934 and are standing well.

Sheet 4.

ABSTRACT ROAD DIAGRAM—SECOND CIRCLE, PUNJAB P. W. D. (B. & R. BRANCH).

Year ________.

	Names of Arterial.	Total milage.	Treated milage unmetalled.	Untreated milage (metalled).	Milage unmetalled.	Bitumen.							Average annual maintenance cost per mile in rupees.
						Surface painted.				Treated otherwise	Surface painted.	Treated otherwise	
						1 coat.	2 coats.	3 coats	Over 3 coats				
	Ambala Provincial Division.												
1	Grand Trunk Road, Art. No. 1 . . .												
2	Ambala Tibet-Ambala Kalka Sec., Art. No. 20												
3	Saharanpur Kurukshetra, Art No. 21 . .												
4	Karnal Kaithal, Art. No. 37 . . .												
5	Kasauli Dharampur Cart Road . . .												
	Jullundur Provincial Division.												
1	Grand Trunk Road, Art. No. 1 . . .												
2	Lahore Ferozepur Ludhiana Road, Art. No, 5												
3	Delhi Multan, Art. No. 6 . . .												
4	Ferozepur Fazilka, Art. No. 17 . . .												
5	Jullundur Hoshiarpur Dharamsala, Art. No. 8												
6	Lahore Moga, Art. No. 31 . . .												
	Gurgaon Provincial Division.												
1	Grand Trunk Road, Art. No. 1 . . .												
2	Delhi Multan, Art. No. 6 . . .												
3	Delhi Alwar, Art. No. 7												
4	Delhi Muttra, Art. No. 19 . . .												
5	Rohtak Bhiwani, Art. No. 22 . . .												
6	Sonepat Kharkhauda Rohtak, Art. No. 36 .												
7	Sohna Rewari, Art. No. 23 . . .												
8	Meerut Sonepat, Art. No. 42 . . .												
	Simla Provincial Division.												
1	Ambala-Tibet Section Kalka to Simla, Art. 20												
	Total .												Average overall.

Mr. S. Bashiram: The papers presented to the Congress this morning afford ample evidence of the fact that tabulation of data on some such lines as those suggested in my paper is necessary as regards the types of road surfaces, materials which such surfaces are composed of and the traffic that they have to carry. Detailed information is essential if we are to come to reliable conclusions regarding the behaviour of road surfaces of various types and under various conditions of traffic and thereby try to arrive at the cheapest possible surface for a given set of conditions.

The method underlying the entries as shown on sheet 3 in the paper assumes knowledge of the normal maintenance practice on roads to which the sheet relates. Details which depart from this normal practice are entered in the next following sheet called the Note Sheet. It is necessary therefore that full information should be available on sheet 3 regarding the normal practice. In the note at the bottom of this sheet information will be found about the quantity and quality of the tar or bitumen used, but the information regarding the gauge of bajri used is missing. This note should therefore be amplified to give this information. I have said elsewhere that our normal practice in the Punjab is to use bajri of 1/8 to 3/4 inch gauge for the first coat and 1/8 to 3/8 inch gauge for the second or subsequent coats.

Sheet 3 as attached to this paper shows the name of a road but I should add that the entries thereon are not altogether correct. Some of the figures given are purely fictitious and are included in the sheet merely to illustrate the method advocated in the paper.

Another important item is missing from the sheet namely information pertaining to the width of a road. This dimension can easily, and indeed must, be indicated if the information tabulated in the set of diagrams is to be of any practical value. A suitable method would be to draw an oblique line after the other traffic census figures shown and then enter this dimension in feet or in yards as found desirable. As an example if the road width is 12 feet the entries shown on sheet 3 against miles 67-73 for the year 1933 would read 256/55 C. I.—17 C. W.—105 M/12.

This morning Diwan Bahadur N. N. Ayyangar advocated that we should consider the gross tonnage on a road and not the intensity in tons per yard width. I too hold the same views. Owing to the absence of bullock carts in western countries the figures relating to traffic intensity are given there in tons per yard width. With bullock carts however the road width is an immaterial factor as these carts keep to one track only and follow in the wake of one another. This being so the figures about intensity of traffic in ton per yard width of road are not so vital to us in India as the number of carts which use the road. This number has been given on my sheet. The gross tonnage and the width of the road being also shown the intensity of traffic per yard width if desired can be very easily worked out.

I have referred in sheet 3 to bitumen and tar only. With a little amplification or change, for example, showing where necessary the miles in a rectangle instead of a circle as suggested in the case of bitumen, information can also be tabulated regarding miles in cement concrete which material is now being widely used in the United Provinces. A suitable entry can also be made in sheet 3 regarding seasonal traffic such as plies *e.g.*, on a hill road or pilgrim traffic.

For purposes of convenience calendar years are shown on sheet 3 while on sheets 2 and 4 financial years have been given. The reason is that figures in sheets 2 and 4 require audited figures of expenditure and these are readily available for a financial year.

In one set of road tables there may be several sheets similar to sheet No. 3 and these should be numbered serially, taking care however that the relevant note sheets are given the same number as their parent sheet followed by a suitable letter of the alphabet, *e.g.*, 3A, 3B, 3C etc., would be the note sheets for miles entered on sheet 3 and 4A, 4B, 4C etc., for those entered on sheet 4.

It may sometimes happen that any particular mile of a road has been renewed more than once during the period covered by any one sheet. Information about this can easily be entered by dividing into two halves the relevant column space on the analogy of the entries pertaining to the first and second coats of tar when two have been given in one year.

I have found as a result of my experience of the use of these tables that it is convenient to have a sort of index which will give by materials the numbers of miles which have been treated with any particular material. Unless this information is readily available, it is always a job subsequently years after, to say which miles were treated with for example bitumen or tar or a mixture of both.

All these tables look at first sight to be rather complicated but short careful study will easily enable one to grasp the principle on which the information has been tabulated, and it is believed that the initial trouble will be amply repaid.

Chairman: I now call upon Mr. V. S. Srinivasaraghava-Achariar to present his paper (No. 18).

The following paper was then taken as read:—

Paper No. 18.

NECESSITY FOR SURFACE TREATMENT OF IMPORTANT TOURIST LINES AND SOME ASPECTS OF ECONOMICAL WORK IN THAT DIRECTION.

By M. R. Ry. V. S. Srinivasaraghava-Achariar, Avl., District Board Engineer, Chittoor (Madras).

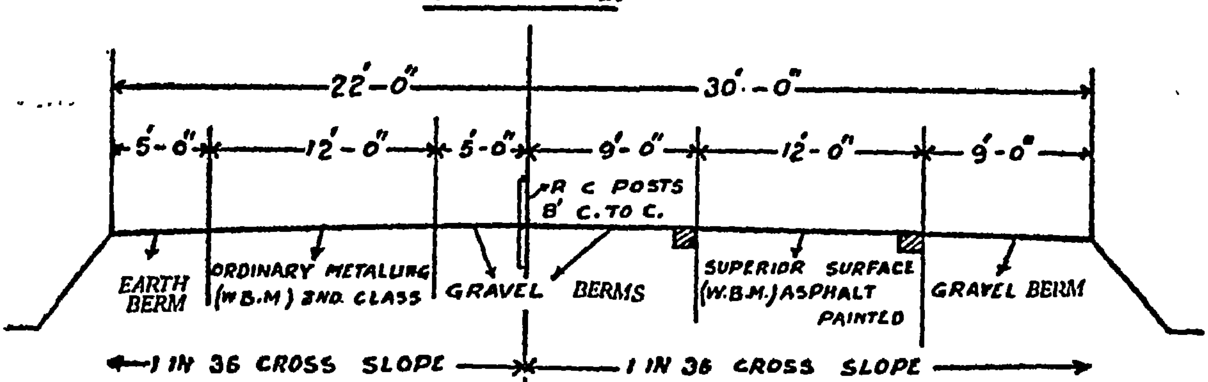
With the advent of high speed motor transport fitted with balloon tyres, the dust problem on our highways has become acute. The usual blinding of water bound macadam with gravel aggravates the problem in dry weather. Dust is worse with laterite and with soft metal. At certain season the roads leading to hill stations such as Ooty, Bangalore and Kodi, become so dusty that it is impossible to follow another car within a furlong or two without being blinded by clouds of dust. This state of things is very insanitary and, apart from damage to motor engines, is the cause of throat trouble and the increase of lung diseases. Road-side property cannot appreciate under these conditions. The object of this paper is to stress the necessity of dust abatement on a systematic programme on certain tourist lines.

2. In this connection the necessity for each District to have a full complement of power rollers, spraying machinery, lorries for watering and transport of materials has to be stressed. Many local boards in South India now realise that such plant is required, but they are unable to find the money. A grant-in-aid for the purchase or replacement of the minimum plant required is very necessary, as otherwise the full benefit of surface improvement grants cannot be achieved.

3. The type of surfacing suitable to each reach of a road should be decided on the basis of traffic census. Surface painting found adequate in the upland Districts may not suffice for the traffic in the plains and near big towns. Table I annexed shows the kind of surfacing considered necessary, in the light of experience of the writer, for various degrees of traffic. The approximate annual cost of maintenance is also stated. For several years to come, one or two coats of surface dressing at a cost of from Rs. 1,200 to Rs. 1,450 per mile is the only practical proposition.

4. There is great disparity between the standard of maintenance of 1st and 2nd class roads in certain districts, the allotments being Rs. 600 and 150 per mile respectively. When country cart traffic is satisfied with a standard of road maintainable at Rs. 150 to Rs. 250 a mile, and a first class macadam road surface painted cost Rs. 1,200 a mile to maintain, why should we not separate the motor and cart traffic where the combined traffic destroys the painted surface which will however easily stand rubber-tyred traffic alone? This separation could be easily effected and might be tried on the Trunk roads within 35 miles of Madras, where there is enough land. A formation width of 52 feet is ample with a concrete kerb in the centre for separation. This system is suggested also by the railway between Arkonam and Conjeevaram where the road and rail traffic run parallel to and almost level with each other separated only by a light fence. Under these conditions, road crossings may have to be made up with concrete or other durable surfacing. Penalties would also have to be imposed by law against the use of the painted surfaces by iron-tyred country carts.

TYPE SECTION OF DUAL ROAD FOR COUNTRY CARTS AND MOTOR VEHICLES.
SCALE 1"=12'.



5. Attention may also be drawn to the impetus given to the use of rubber-tyres on country-carts in the Bombay Presidency, where the carts using rubber-tyres will be exempt from the tolls. Though tolls have been abolished in Madras, encouragement might be given through better rates to departmental carriage contractors or exemption from wheel taxes. It is well known that in the process of repairing one mile the neighbouring miles get worn out by the iron-tyred and overloaded carts carrying metal.

6. Examining the road conditions, in an average district in South India, the immediate improvement required is:—

(1) to increase the thickness of metal-bed to at least one foot as a foundation necessary for any future improvement;

(2) to construct shoulder walls (about 12 inches wide and 10 inches deep) on the open high way where metalled width is only 12 feet to protect the edges of the metalling from damage by carts passing from the centre of road to the berms and *vice versa*. The destruction is intensive in Districts like Coimbatore and Chittoor where brakeless country carts damage the edges by using the earthen berms to limit their speed in going down hill;

(3) to introduce better specification and practice in the consolidation of water-bound macadam;

(4) to ensure the provision of adequate plant, *e.g.*, rollers, lorries, sprayers, etc., in each district;

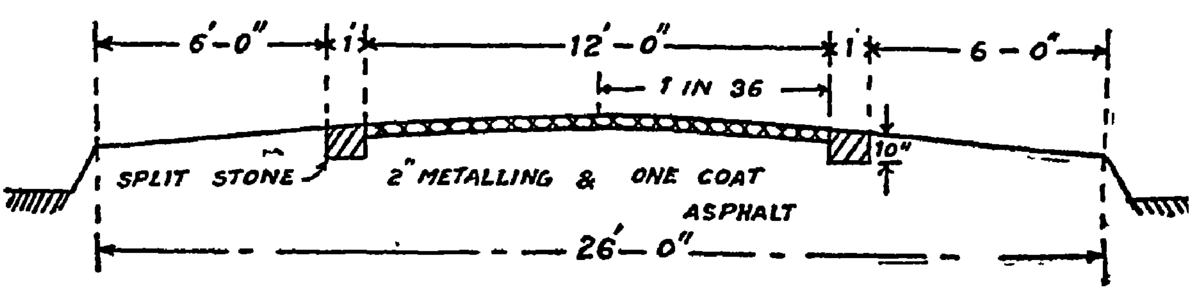
(5) to devise a more efficient control in the timely collection and consolidation of materials.

7. With regard to (1), cheap soling metal in two or three layers may be used and consolidated by heavy rollers and all money spent on this work will go to the capital cost of the road.

(2) Shoulder protection is not only necessary for water-bound macadam particularly on gradients but also for the edges of asphalt or tarred surfaces. This work is therefore required throughout improved sections. A neat result is achieved by using split stone, 12 inches by 10 inches, set dry. The cost of such walling on both sides is estimated at Rs. 125 per furlong.

TYPE SECTION—ROAD

SHOWING SHOULDER PROTECTION.



(3) Detailed Standard Specification (Madras, No. 96), applies to consolidation; but experience suggests certain modifications. The minimum thickness of metal required for resurfacing may be taken as two inches consolidated. This is more economical than the standard specification and is the maximum that can be easily consolidated by a stone road roller. The consolidation of the metal should be stopped before it is "thoroughly hard and smooth" and gravel blinding should be added to the wet consolidation when it is about three quarters complete. With a metalled width of twelve feet and less a cross camber steeper than 1 in 36 is harmful to the road, as all cart traffic is forced to the centre and "tracks".

8. All is not over with the consolidation of metal and mere watering for 15 days more. When traffic is allowed on a newly metalled surface there is a tendency for the metal to shift and consolidation to be disturbed. Re-rolling three to five days later with copious watering and sand finishing is found to give a more permanent set and better wearing surface than that advocated by the standard specification. Consolidation done when the road bed is dry is better than that done during the monsoon over a

saturated bed. Nor is it true that the softest metal that will carry the traffic is the best because it makes a smooth surface and forms its own blindage.

9. The advantages of power rollers are not fully realised. The number of rollers required for each District depends on the average mileage that has to be renewed annually. Taking 10 to 12 miles as the average outturn of each roller the number of rollers should be decided with a 25 to 30 per cent. margin for reserve. One or two water lorries are also essential if metalling is to be started before the monsoon; and, in the maintenance of asphalt sections, a special lorry fitted with a sprayer and also to carry other materials required for patch repairs will be a valuable addition.

10. To achieve a uniform result over a large area, there appears to be necessity in this Presidency for better control over administrative units to ensure the timely collection and spreading of road materials. Consolidation by power rollers under ideal conditions and to proper specifications will give a mosaic and uniform wearing surface, which will need no heavy gravel blindage and should last from one to three years longer than work done with a *stone* roller. This is the first step to be taken in the reduction of dust on the roads.

11. The weak spots where dust from passing wheels is most felt and where undue wear of the road surface is to be kept down are:—

(1) Over bridges between parapets.
(2) In towns and villages with house property abutting on the road.
(3) On sharp curves where motor vehicles cornering at speed unravel the surface.
(4) In ghat sections of roads, with hair-pin bends and also on steep gradients.

12. Of these, (3) and (4) can be mitigated by proper super-elevation, but the dust problem can be fully solved only by surface painting. The weak spots will not be many in each district, and improvements should be taken up at once all over the Presidency from maintenance or special grants. Asphalt and concrete have passed the stage of experiment, but district road staffs must be trained and gain experience in the use of new materials and in their several coats. The idea that all experiments should be carried out in one district before a move is made in others is not altogether satisfactory. The main point is to determine the behaviour of different surfaces wear under varying traffic and local conditions. The Madras Government have recognized the educative and other value of doing special surfacing from maintenance grants at costs within Rs. 4,000.

13. Apart from the amount of traffic, the progressive types of road surfaces are really an index of the wealth of the community maintaining them. It is axiomatic that where an improved surface is necessary because of "foreign" traffic additional revenue must be tapped in the form of tolls or non-recurring grants from outside the community.

14. The first step recommended in order to allay dust in a section of road where the water-bound macadam surface is in fair condition for moderate traffic (below 500 vehicles per day) is to apply one coat of spramex. Normally, if the traffic does not exceed that figure, the surface paint may not need renewal for three years.

15. For slightly heavier traffic, two coats of surface dressing may be needed at the outset. Hot asphalt is not recommended for both coats, as it becomes soft and tacky under traffic, but a combination of a first coat of hot asphalt and a seal coat of colas may do. Asphalt emulsions in single or double coats never bleed under the sun and hold the granite

chips well in place and the surface is non-slippery. Emulsion surfacing in two coats is to be preferred in ghat sections where foot-hold of draught animals and non-slipperiness are the main desiderata. Cold emulsion is very handy as a material for surface repairs and has therefore a great future in the maintenance of dustless roads. With the increased knowledge of the chemistry of such emulsions it should be possible for every district engineer to get his stock prepared afresh for the season and distribute it in trucks. One defect of emulsion, however, is the lack of body and the best results will be obtained by a combination with a bottom coat of asphalt and tar.

16. In an experimental stretch of surfacing done in mile 100/1 of the Madras-Bangalore Road, Shalimar road tar No. 2 was used for the first

Photo No. 1.—Concrete-*cum*-asphalt construction; mile 115/1, Madras-Bangalore Road.

Photo No. 2.—Shalimar Tar No. 2 sealed with Colas; mile 100/1, Madras Bangalore Road.

coat and "Colas" for the second. Tar, though soft for some time after spraying, improves in hardness and the surface does not soften under the Sun's heat nor do wheel marks develop under country carts.

17. To sum up the experience gained in Chittoor District, the following combination seems to answer well:—

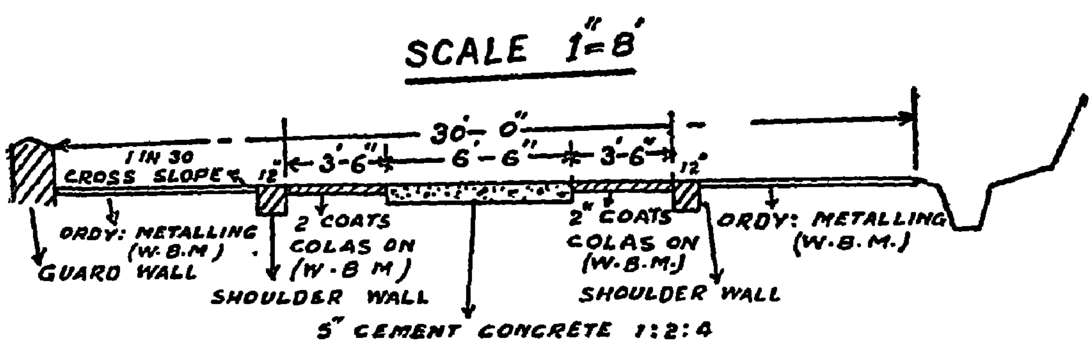
(1) Two coats of Colas—in ghat sections.

(2) One coat of Spramex with medium traffic—in level country.

(3) One coat Spramex or Road Tar plus a sealing coat of emulsion—in level country with heavy traffic.

18. A photo showing the concrete-*cum*-asphalt construction done in September 1933, in mile 115/1 of the Madras-Bangalore road, appears on page 78. There has been no wear in either the concrete or the Colas. The difficult problem of maintenance of the road in the ghat section has been satisfactorily solved and the road is now dustless and better riding qualities have resulted.

19. The cross-section of the ghat section of the road is shown below:—



On the untreated portion of the ghat road bandies using the side berms cause ruts to develop and damage the edges of the metalling. Here is a case for a wall to protect the edges, and this is included in the maintenance programme of the year together with the surface renewal and treatment with two coats of colas.

20. A photograph is also given (on page 79) of the two-coat treatment with tar and Colas on the Madras-Bangalore road. This has a hard and smooth surface and does not become tacky under the Sun. On the same road the surfacing over a bridge with 3 vents of 60 feet was done with 3 inches of concrete (1: 2: 3), as wearing layer over reinforced concrete decking. This has been under traffic since April 1933, and shows a mosaic surface. The cost of construction was Rs. 4 per square yard. There has been no expenditure on maintenance except filling the joints twice a year with mexphalt. The surface of the bridge has been freed from dust.

21. *Records of Construction and Maintenance costs.*—A sample form as adapted from L. F. Form No. 69 is reproduced on page 82 showing the record of work done each year in the construction or maintenance of surfaced roads. This will give not only the metal renewals done but also the cost of special surfacing and its maintenance. Symbols are used for various materials and the number of coats. Mile and furlong stones on the road are also marked to denote surfacing and year of work, thus:—

T_1—35 on furlong stone shows Tarring one coat done in the year 1935.

S_1—34 on a furlong stone shows Spramex one coat done in 1934.

22. A form (page 83) is also suggested for keeping accounts for carrying forward savings on maintenance to a reserve fund to the credit of the particular section which has been taken up for special improvement. A standardised form of statistics with similar forms for maintenance costs of improved surfaces, together with a generous policy of educating Road Engineers in the construction of new types of road surfaces is sure to result in the general improvement of roads in this Presidency.

TABLE I.

	Daily traffic.		Nature of surfacing.	Cost of construction or renewal.	Cost of maintenance per annum.	Remarks.
	Country carts.	Motor vehicles.				
				Rs.	Rs.	
1	100	20	Water Bound Macadam 2nd Class.	1,200	250	This is the standard adopted for 2nd class roads in the Presidency.
2	100 to 200	50	Water Bound Macadam 1st Class.	2,000	500 to 600	Standard for Trunk roads.
3	200 to 300	250	One coat surface dressing with shoulder walls and 2″ renewal and 12′ wide.	5,000	1,200	
4	200	500	Combined Water Bound Macadam to 2nd Class standard and asphalt surfacing one coat, apart from road widening and soling.	6,200	1,350	Life 4 years for water bound macadam and 7 years for asphalt portions.
5	300 to 500	500	Two coats surface dressing with shoulder walls and 2″ of renewal and 12′ wide.	6,200	1,450	
6	Do.	Do.	Cement Macadam 4″ thick with shoulder walls at Rs. 2-8-0 per sq. yd.	20,000	2,100	Life assured at 10 years.
7	1,000	above 500	Concrete road 6-4-6 and 12-4 and 12′ wide with shoulder walls.	30,000	2,100	Life assured at 15 years.
8	1,000	above 500	Concrete road 0-6-0 reinforced suitable in deltaic area.	50,000	3,400	Life assured at 15 years.

Form of records proposed for surfaced roads.

REFERENCES.

▨ = Metalling.
M.R. = Metalling Power Roller.
M O. = „ Ordy. „
S_1 = Spramex One Coat.

T_1 :— Tar One Coat.
C_2 :— Colas Two Coats.
Cost :—Capital or Maintenance.

(ADAPTED FROM L. F. FORM No. 69.)

Name of roads.	193 -3				193 -3				193 -3				193 -3				193 -3				193 -3			
	Locality.		Cost.		Locality.		Cost.		Locality.		Cost.		Locality.		Cost.		Locality.		Cost.		Locality.		Cost.	
	M.	F.	Metalling.	Surfacing.	M.	F.	Metalling.	Surfacing.	M.	F.	Metalling.	Surfacing	M.	F.	Metalling.	Surfacing.	M.	F.	Metalling.	Surfacing.	M.	F.	Metalling.	Surfacing.

Form proposed for watching savings under maintenance for a reserve account.

Name of Road.	Reach of Road.		Total Length.	Allotment per mile ear-marked.	Expenditure in year.		Savings in the year.	Previous savings B. F.	Total funds to be marked to Reserve account.	Remarks.
	From M. F.	To M. F.			Renewal.	Repairs.				

Mr. V. S. Srinivasaraghava Achariar: This Paper has been written by me with the experience I have gained in some of the Upland Districts and motor roads in the Madras Presidency. My experience shows that there is still scope for improving the standard of water-bound macadam surface. In a combined traffic of less than 750 vehicles in which bullock carts preponderate it is quite easy to improve the water-bound macadam. Where the dust nuisance is very great, as on the tourist lines, we can have one or two coats of asphalt. I have described in my Paper an experiment I have made in those tourist lines. There are one or two interesting points to which I wish to draw your attention. Where the motor trafic is not so heavy as 'bandy' traffic a single coat of spramex keeps going for about three to four years. Where there is more motor traffic there should be two coats of painting. Where the two coats are employed it is better to have the first coat with tar and the second with an asphalt emulsion and this stands the traffic better.

Another experience of mine has been that in the ghat sections where it is difficult to maintain proper sections, asphalt *cum*-concrete, as tried on the Madras-Bangalore road, is found to be better. This surface on the Madras-Bangalore road has stood well for three years. It is found that while the 'bandies' going up the ghat keep to the concrete part those coming down avoid it.

In page 81 of the Paper, I have referred to the fact that when there is a heavy combined traffic of bandies and lorries exceeding one thousand it is cheaper to separate the two kinds of traffic into different parts of the road. But some friends have suggested that it would be difficult in India to separate the streams of traffic in this manner. This is true to a great extent. The present metalled width of the average road is only 12 feet. In such cases you cannot separate the streams of traffic as suggested. But if the road is widened such separation can be effected. I think with some penalties imposed here and there and with the power the motorist wields (laughter) separation of the two streams of traffic will not be a difficult proposition. After all the bandy-wallah does not like to keep shifting his track frequently.

Chairman: I now call upon Col. G. E. Sopwith to present his paper.

The following paper was then taken as read:—

Paper No. 20.

THE ROAD PROBLEM IN INDIA WITH SOME SUGGESTIONS.

BY

COL. G. E. SOPWITH.

The author has ventured to write this paper partly as the result of papers read and discussed at the inaugural meeting of the Indian Roads Congress and partly by his firm conviction that the most important stimulus to an increase in general prosperity lies in the cheapening of the transport of agricultural produce (since India is predominantly agricultural, a predominance that will in all probability exist for a long

period) from the village to the distributing centre. This can only be effected by the improvement of existing and the construction of new feeder roads. It is of no little interest and practical importance to note that the recent development of well constructed earth roads in the Peshawar District has cheapened the transport of agricultural produce by 3 to 8 annas per maund and that an important Zemindar, now a Minister in the Punjab Government, recently declared in a speech at the annual dinner of the Punjab Engineering Congress that the Zemindar owed a debt of gratitude to the Engineers of the Public Works Deptt. for the improvement of feeder roads which, so far as his own land was concerned, had resulted in a saving in transport of 4 annas per maund of agricultural produce. The whole of this saving goes into the pockets of the owners or tenants of the land and the huge aggregate sums represented by the savings in transport are available for increased purchase of trade goods and so increase the general prosperity of India. This aspect of the question has not perhaps always received as full publicity and recognition as it deserves. The financial authorities of Governments are naturally somewhat apt to look on the Public Works Departments as spending (or "non-productive") departments only and to grudge allotting money (in the absence of absolute necessity) unless a direct return can be foreseen. The savings in transport, leading as they do to increased prosperity, also tend to increase the indirect returns by way of taxes, etc., and it may interest delegates to know that Lt.-Col. Wakely, C. R. E., Peshawar, obtained enthusiastic support for the net-work of earth roads, for the inception of which he was responsible, by first carefully estimating the indirect returns in close consultation with district officers and then putting up a complete reasoned argument instead of merely putting in an estimate of cost. The scheme thus took on the form of a sound commercial proposition. Financial authorities, hard headed as they must be, are in the author's own experience much more likely to be sympathetic to the presentation of a road scheme in this form than in the form of a mere bill of costs. The author does not wish to imply that this method is not adopted but does feel that many engineers consider such a preliminary investigation to be outside their sphere and that in consequence their enthusiasm is often damped by the refusal of funds. In all Government Departments there is water tightness. His Excellency the Governor of the Punjab in his address to the Punjab Engineering Congress laid great stress on this. The author knows that the more this water tightness is broken down the easier is the path of the enthusiastic road engineer.

2. At the present time many carefully planned road schemes are under investigation by the various Governments and the Road problem in its relation to the prosperity of the country is clearly being recognised as of prime importance. The path of the enthusiastic road engineer is therefore easier than possibly it has ever been. Given that improved roads and the provision of badly needed feeder roads is an accepted principle of sound commercial value, the problem arises as to the type of road that is suited to and necessary for the traffic it is to carry.

3. The late Mr. Adami in a valuable and interesting paper* presented to the First Indian Roads Congress in December 1934 put forward certain principles and suggested certain conclusions from which the author feels compelled to differ to a certain extent principally as regards surface

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* Paper No. 6.

painting. Mr. Adami advanced definite criticisms of this process (specifying that his remarks apply to asphalt in paragraph 16 of his paper) which may be summarised as follows:—

(a) A well consolidated sub-grade is necessary.

(b) A thin film only is deposited which can only be expected to carry motor traffic since iron tyres quickly cut through the film.

(c) The effect of periodic re-painting is to build up a thick mat excessively rich in bitumen liable to waving and corrugation.

4. Taking these criticisms in order:—

(a) The author submits that it is not economical to treat any road surface, whether by *painting or the application of a carpet, which is not* absolutely solid and sound. A sound foundation whether natural or artificial is a *sine qua non* for all roads. If a road is uneven, rutted or potholed then it is an axiom to say that the inter-locked structure of that road has begun to deteriorate and it is, in the author's view, a most unwise proceeding to carry out any treatment cheap or expensive till a properly interlocked waterbound structure has been recreated. To ignore this and to trust to luck is too risky a proceeding for, if failure of the sub-grade occurs after a few years then the whole expensive superstructure will give way and all will be to do over again with the added cost of reconditioning the sub-grade instead of having only to provide periodic inexpensive renewals if the bituminously held surface is put into proper condition to start with. The author feels sure that there is general agreement that a long view is the only one permissible and that opportunism in considering road problems is contrary to economy and sound finance. He therefore regards a good sub-grade as an essential before any form of treatment is started. That there are occasionally sub-grades, obviously solid but slightly uneven on the surface, suitable for treatment is undoubted but such conditions are in a very small minority and there are few untreated roads in this country which, if not immediately suited to treatment of no matter what type, do not require reconditioning. This reconditioning to-day is not so formidable a business financially as it used to be. *The old custom was to remetal with 6 inches of* metal. This was then reduced to 4½ inches and such is still the usual custom on waterbound roads in many areas. If a surface is to be treated after reconditioning of the sub-grade, 3 inches of metal measured loose is ample and this saving in metal goes a long, if not all the way to paying for the cost of the material to be used in treatment. By the system of cheap renewals mentioned in paragraph 4 of Mr. Stubbs' paper presented to the International Road Congress and also to the Indian Road Congress* the quantity of new metal required is equivalent to from 2¼ to 1½ inches thickness of loose metal.

5. It is of importance to note that when reconditioning of the surface is in progress the road should be brought to a camber not greater than 1 in 48 and preferably 1 in 72 as thereby there is less side thrust, less tendency to skid and less urge for traffic to track. While on this subject, it is of interest to note that when reconditioning roads especially hill roads, it is comparatively cheap to super-elevate on curves. If efficient

* Paper No. 5 (a).

super-elevation is given, by which side thrust is practically eliminated, tar painting is all that is required to stand up to the wear of traffic round the curves.

6. The author holds that it would not be safe to ignore the cost of reconditioning as a definite item in the financial aspect of road improvement regardless of what type of treatment is intended to be super-imposed and he has therefore included this cost in the figures given later under the heading of financial factors involved.

7. Before leaving the subject of sub-grade reconditioning it is desirable to emphasize, as has so often been done before, the fact that interlocking of the stone metal particles is essential to attain lasting results. This implies that, so long as really good road making stone metal is available, no admixture of earth or other substance should be allowed. Alas! in many places in India metal is either soft or friable and liable to crush easily and in such instances it is necessary to add a certain amount of other material to fill voids and to give lateral and cushioning support to the metal during dry consolidation. In Cawnpore broken kankar has been used with success in this connection and, being much more suitable for brushing out of joints for surface painting than is moorum, delegates may be interested in this fact. In any event the admixture must be only sufficient to fill voids and must never be so excessive as to give a resultant effect comparable only to plum mud concrete, for without interlocking it cannot be said too often that lasting stabilisation cannot be attained. In the ordinary course of waterbound reconditioning work, during the wet consolidation stage, the mud and small stuff existing in the old surface is forced up into the voids below the planes of contact of the stone particles while the stone particles themselves settle down into firm combination with the metal of the old surface. This creates a cushion which is of the utmost value, especially when the metal is liable to fracture or crushing, giving support both from below and laterally. This support is one of the advantages claimed by Mr. Stubbs for his system of pre-mix waterbound macadam and there is no question of its immense value. This subject will be referred to again later when dealing with carpets.

8. As regards (b), it may be true that asphalt or bitumen will only form a thin film on a surface on which it is painted but such is definitely not the fact when tar is used. The high surface wetting capacity of tar when applied to stone surfaces and its power to absorb an appreciable amount of clay, kankar and such like substances gives it a high penetrative quality when applied to a surface. Suggestions for the quantity and grade of tar to be used for surface painting will be given later in more detail but it can be said here that for heavy bullock cart traffic an application at 44 pounds per hundred square feet (1/3rd gallon per square yard) will penetrate along the planes of the stone metal to a depth of at least 1 to 1½ inches in addition to binding the surface material in the voids to a reasonable extent. (It is important to note in this connection that painting should be done as soon after the consolidation as possible, that is, as soon as the road has dried out to a depth of 2 inches which will take from 4 to 28 days according to climate. To neglect this means too severe clogging of the surface voids leading to less penetration and an opportunity for the various causes of deterioration). The effect of this penetration is to hold firmly the interlocked metal in its place in relation to other particles. It is bullock cart traffic that is the bane of Indian roads and it is their wheels, with narrow iron tyres, usually convex and

therefore concentrating the heavy weight on a very narrow width, which cause the movement of one particle against another and so the rounding of edges and forming of potholes and ruts. Bound by well penetrated tar this evil is overcome and those of the delegates who went on the first tour of the Congress will recollect that with this cheap and simple treatment on such heavily trafficked roads as that from Nowshera to Peshawar, the McLeod Road in Lahore and many others, the bullock cart and its evil effects have been defeated for many years. Produce a method of treatment that will defeat the bullock cart wheels of the present day and it is suggested that the whole road problem is solved. In writing this the author has not lost sight of the admirable invention of the Dunlop Rubber Co. with its pneumatic tyred wheels but he fears that, however extensively it may be taken up in concentrated towns, it will be long before the villager will adopt it largely. The problem of producing roads which will stand up to the iron tyred wheel is therefore ever present with the engineer, but the possibility of extensive adoption of pneumatic tyres makes it all the more incumbent on the engineer to produce an effective guard against damage by iron tyres at the cheapest possible cost. In certain parts of India, notably the Madras Presidency, the criticism is often made that the wheels there are narrow, and "wobbly" and the tyres flat resulting in a good imitation of a razor edge working on the road. This action on a tarred road would direct itself to grinding away the stone metal of the surface or, if there had been two or more coats, the chippings. It is therefore held by some that surface painting would not stand up to such traffic. It has already been pointed out that the tar used has penetrated into the body and is not a film on the surface. Consequently the action would be against the stone only and the same deleterious action would take place in the stone of a carpet. Possibly a cement concrete road would stand up to this action but later, when considering the question of finance, it may appear doubtful whether it would be worth while embarking on so expensive an expedient if a much cheaper treatment will do.

9. The author offers the suggestion that it would pay to provide all iron tyred carts with 3 inch wide wheels of the type used in the north in order to save vast sums on the method of treatment; always assuming that the carters will not listen to the arguments for pneumatic tyres. It is admitted that this is a somewhat retrograde suggestion, but, in existing circumstances, its practicability is worth considering in the author's opinion.

10. Before leaving the subject of a first coat a word is necessary about the chippings or gravel used to blind the tar. With an application of 44 pounds per 100 square feet sufficient tar is left on the surface to hold 3 cubic feet of chippings per 100 square feet. These chippings should be $\frac{3}{4}$ inch to $\frac{1}{8}$ inch, the larger size being necessary because a well consolidated waterbound surface is not smooth but, consists of miniature peaks and valleys and the main function of the chippings of the first coat is to fill up these valleys thus forming a mosaic surface as well as giving lateral support to the upper portions of the stone metal. It is assumed that the stone metal used in the waterbound macadam consolidation is graded down from two to one and a half inches. Where it is customary to use metal graded one and a half inches downwards, half to one-eighth inch chippings should be used.

11. Although the early application of a second coat is not necessary, the author has found it to be a sound practice economically, since a fair proportion of the main body of the sub-grade is visible after the first coat for the reasons given above and is therefore subjected to direct wearing action. To apply a second coat 2 months after the first is definitely sound (that it is not necessary is proved by the author's experience in Peshawar where second coats were applied 3 years after the first owing to the difficulty of financing; he was not so fortunate in persuading the authorities as was his successor Lt.-Colonel Wakely, at a later date!). What this second coat should consist of, depends entirely on type and intensity of traffic and on the wear resisting qualities of the chippings. Too often does one hear of tar failing or bitumen failing and so on, when the *real* cause of failure is usually an error in application of the binder or in the stone itself. Traffic is, and should be, carried by the stone and the function of the bituminous material, whether tar or bitumen, is to bind that stone together not to replace it as a surface for carrying the traffic direct. The surface of a road should present a mosaic pattern with but little evidence of any bituminous material existing. Chippings are always cheaper than the binder and consequently the harder and tougher the chippings and therefore longer lived under traffic, the thicker and more compact mat formed by them the better, since thereby their life is extended; the guiding principle being that a new paint is unnecessary until the chippings are worn right through to the original stabilised surface. It is of importance to note in this connection that tar sets hard and does not creep over the top of the chippings, a fact which bulks largely in producing the well known non-skid properties of tarred roads. If the chippings or gravel are of so good a quality as to wear, through surface friction of traffic, only half an inch in say 3 or 4 years, it is sound to produce a mat half an inch thick. This takes 4 cubic feet of $\frac{1}{2}$ to $\frac{1}{4}$ inch chippings per hundred square feet and 28 to 30 pounds of tar. If on the other hand chippings are of poorer quality and would wear away three-eighths of an inch in one year, it is better to save money on the binder and to use only 2 cubic feet of $\frac{3}{8}$ to $\frac{1}{4}$ inch chippings with 14 to 16 pounds of tar. It is clear from this that it often pays to get good chippings from a distance rather than to use local chippings merely because they are cheap.

12. The suggestion is offered that when really tough chippings are expensive their application might be restricted to two foot widths of road; cheaper and less tough chippings being applied to the remainder of the road. This applies only to roads less than 16 feet wide as experience shows that tracking in roads 16 feet, or more, wide occurs to a much less extent. Economy in maintenance can only be attained by so designing the work that periodical renewals are only required after two, three, or more years. The author does not propose to deal with the oft repeated assertion that tar will deteriorate within that period beyond remarking that many delegates saw the proof that this is a fallacy when touring the Peshawar District last year and that the impression is a relic of the days long gone by, when crude tar was used and in no way does it hold good in respect of modern tars.

13. Regarding (*c*) *i.e.*, periodical renewal coats leading to a gradually thickening mass liable to waving and corrugation, enough has been said above to show that this cannot occur with tar since renewal should be carried out only when the mat of chippings is worn down to the original surface. The tar binding these chippings is mostly in the joints between

these chippings and wears down as the chippings wear from surface friction, consequently the thickness does not increase with periodic coats. Sections taken from the McLeod Road and the Mall Lahore, the former subject to heavy bullock cart and other traffic and the latter to much motor traffic show only a thin skin apart from the tar which has penetrated and no waving or corrugation has occurred although it is ten years since the former and nineteen years since the latter was treated.

14. We now come to a consideration of the desirability or necessity of carpets. Tar painted roads treated with a first coat of 44 pounds per hundred square feet have been proved to stand up to traffic as great as 1,000 tons per yard width a day, those treated with 28 pounds to 300 tons and those treated with 33 pounds to 400 tons. A one inch tar carpet made with really good stone should stand up to the same traffic as does a road treated with 44 pounds but it does not always do so. The author suggests that the reason for this may be in the fact that the carpet is often laid on a hard surface to which in many instances it only adheres by means of a priming coat instead of forming a close union with the sub-grade. This would not matter if the carpet were of a really dense type but as this is very difficult to attain under Indian conditions, as Mr. Adami pointed out, the very important cushioning effect is not present to a sufficient degree and the metal particles are forced apart by the pounding of fast traffic and if the stone be friable it is crushed at the point of junction with the sub-grade. The author therefore believes that more uniformly good results are obtained by painting with tar than by using a one inch carpet and suggests that the latter is best suited to conditions where an exceptionally level running surface is required and traffic does not exceed say 750 tons per yard width per diem and he definitely recommends surface painting rather than a thin carpet in other circumstances. The author believes that Mr. Stubbs introduced his method of pre-mix waterbound macadam in order to achieve the cushioning effect. Unfortunately in practice too much water is often used with the result that the clay and small stuff underneath is forced right between the pre-mixed particles, the tar absorbs it, thereby losing its adhesiveness, and the carpet falls to pieces rapidly. That excellent results have been obtained by Mr. Stubbs and Lt.-Colonel Wakely when using this method is undoubted but it requires more than ordinary supervision which the staff at the disposal of P. W. D. Engineers in these days of economy is too sparse to provide adequately. That the idea is an extremely sound one based on scientific principles is certain, if the author may be permitted to say so without appearing to be patronising to the introducer of the system.

15. It has already been said that penetration by using 44 pounds of tar is at least 1 to 1½ inches and owing to the metal being fully cushioned its effect is at least equal to that of a 1½ inch carpet. If the traffic is so concentrated and intense as to render this insufficient a carpet of 2, 2½ or 3 inches consolidated thickness is indicated, though recent experiments, using a first coat of 50 to 54 pounds of tar No. 1 to increase penetration, have given astonishing results under the heaviest bullock-cart traffic. Such conditions occur in narrow city streets, streets leading to docks and similar areas and short lengths of roads leading from brick fields to large cities. There is little doubt that practically any traffic met with in India can be dealt with by constructing a 2½ or 3 inch carpet but partial failures have occurred and these are nearly always the result of crushing of the

stone due to insufficient cushioning when the stone itself is not hard enough to stand without it. Mr. Adami has given us his views on this point and at his suggestion the pre-mix bitumen carpet known as Shelcrete embodying only stone and sand, has been brought into being. A trial on similar lines with a tar bitumen mixture at Delhi has been made and has so far stood up well. Similar experiments using tar alone seem also to indicate that the principle is sound. All modern experience in Great Britain, America and the Continent, emphasizes the importance of the most exact grading of aggregate down to fine stone dust in order to get maximum density and thereby complete lateral support for the larger particles. To attain this it is necessary to have the most elaborate and expensive mechanical stone crushers, disintegrators and mixing plant and this is quite unattainable in India, at the present time except in places where there is extensive concentrated carpet work such as Bombay and Calcutta. We must therefore cut our coat to our cloth and the use of sand seems to be a move in the right direction if not ideal. Where the stone is not liable to crush, the question loses most of its importance but it is one of definite importance when stone is friable or tending to softness. Experiments are continually being made to improve methods and in the course of the next year or two valuable headway should be attained.

16. The conclusions which the author has come to to-day are:—

(a) Reconditioning of the surface is nearly always a real economy and can nowadays be done cheaply by using the "cheap renewal" methods advocated by Mr. Stubbs and reported in "*Indian Roads*", March 1933.

(b) Surface painting with tar, using No. 1 for the first coat (on account of its superior penetrative quality) at a minimum rate of 33 pounds per 100 square feet and a maximum of 44 pounds, according to intensity of traffic, blinded with ¾ to ¼ inch chippings at 3 cubic feet per 100 square feet, is the most fool proof and satisfactory method of treating a road carrying from 400 to 1,000 tons per yard width per diem (this load could only be carried when stone is really good; with friable stone it would not be safe to assume more than two-thirds of this), where traffic is up to 2,000 tons per yard width an application of 54 pounds per 100 square feet will, according to the latest experiments, hold up. Second coats to be, according to traffic and quality of chippings, of No. 2 Tar (in dry hot climates) No. 3 Tar (in more humid and hill districts) and High Viscosity Tar (in every humid districts), at the rate of 16 pounds to 28 pounds per 100 square feet with chippings from 2 cubic feet to 4 cubic feet per 100 square feet.

(c) One-inch carpets to be used where traffic is not more than 750 tons per yard width per diem and normally where a specially level surface is required or where the sub-grade surface is sound but slightly uneven.

(d) Where a heavily painted road cannot stand up to traffic a carpet is required of 2 to 3 inches consolidated thickness, but a single coat, at 54 pounds, appears to be equal to a 2½ inch carpet.

(e) The method of obtaining maximum density and so lateral support requires further investigation. It is not of outstanding importance when first class hard stone metal is available but comes into prominence when metal is somewhat soft or friable. The use of sand seems to be a move in the right direction.

17. There remains a consideration of the financial factors involved. The cheapest method is not necessarily the most economical but if a cheap method enables a road to stand up to the traffic, involves capital costs of a not too astronomical a character and involves only inexpensive periodical repaints the author submits that such a method should be followed as it is certain that India cannot afford to spend unlimited funds on its roads and the spending of large sums per mile on roads which the author submits from his experience can be treated for a much smaller capital sum can only lead tc great lengths of roads being left untreated and to the improvement of the very important feeder roads from villages to distributing centres receding further into the distance.

18. Perhaps the simplest way of illustrating the financial aspect is to set forth certain figures which the author has carefully estimated for the existing metalled roads of the Madras Presidency. He has, so far as painting and carpets are concerned, allowed for the cost of reconditioning the waterbound surface before treatment. The length of metalled roads is 23,415 miles according to the Mitchell Kirkness report.

The cost of reconditioning waterbound surface and applying two coats of tar	=Rs. $18\frac{3}{4}$ crores.
Reconditioning and laying a 2 inch carpet . .	=Rs. $33\frac{1}{4}$ crores.
Cement Concrete Roads	=Probably at least 60 crores.
The annual maintenance of the tar surfaces once completed would be	=Rs. $1\frac{3}{4}$ crores.
Assuming that money is obtainable at 4 per cent the interest on the difference in capital cost between a tar carpet and painting would be . .	=Rs. 58 lakhs, or $\frac{1}{3}$rd of annual maintenance charges.
Interest on difference between capital cost of cement concrete roads and tar painting	=Rs. 165 lakhs (practically equal to the annual maintenance cost of surface).

19. The author suggests that with tar painting a really substantial attack may be made on the problem and he is confident that such treatment will stand up to the traffic now carried or likely to be carried within reasonable time by 95 per cent of the roads in India.

20. One point raised by Mr. Adami the author feels called on to mention. He states that the system of surface painting is not economical because the asphalt used is equivalent to 9 pounds per cubic foot. This is on the assumption that it lies as a film on the surface. Taking the minimum penetration of tar as one inch with 44 pounds and assuming the chippings so good that a second coat at 28 pounds is justified 72 pounds of tar are used in a consolidated mass of $12\frac{1}{2}$ cubic feet or $5\frac{3}{4}$ pounds per cubic foot (equivalent to $4\frac{1}{4}$ pounds per cubic foot loose).

21. For a $1\frac{1}{4}$ inch carpet (consolidated mass) the quantity used would be (no priming coat is necessary) 70 pounds. It will therefore be seen that the method of painting where thorough penetration takes place is just as economical while the cost of the actual carrying out of the work is very definitely cheaper.

22. The author must also refer to para. 7 of Mr. Stubbs' valuable paper* read before the International and Indian Road Congress, wherein it is stated, *inter alia*, that "the suppliers of tar claim that after a certain number of annual applications, say four or five, it will only be necessary to paint road surfaces once every other year". The author greatly regrets that by an oversight he misread this passage and consequently did not comment on it at the time. All manufacturers of modern tars claim, and hold that their claim is proved, that annual applications are not only not necessary but may be a definite disadvantage as well as being unnecessarily expensive. The author does not doubt that Mr. Stubbs was under a misapprehension when quoting the manufacturers as holding the views stated.

Col. G. E. Sopwith: There is only one point I would like to mention in connection with this Paper. To obtain the best results from the painting of road surfaces it is essential to apply the first coat at the earliest possible moment after reconsolidation. In miles 7 and 8 of the Mysore Road which we saw three days ago the result of this not having been done over the first 5 furlongs is a plain illustration of the difference which you get if you leave the road unpainted for too long after reconsolidation. In the first 5 furlongs, as you saw, there was a lot of tacking in several places showing that Tar had not properly penetrated.

The painting was done more than 6 months after reconsolidation on these 5 furlongs. In the last 3 furlongs where the first coat had been applied between 2 and 3 months after consolidation, which is not as early as is desirable, the incorporation of the Tar in the road surface was definitely better.

At this stage the Congress adjourned for the luncheon recess.

DISCUSSION ON PAPERS (NOS. 17, 18 AND 20) in GROUP 2.

The Congress reassembled at 2-15 P.M., after the luncheon interval with Mr. H. Hughes in the chair.

Chairman: Gentlemen, we might now continue discussions of the second Group of papers. There is a small point I wish to refer to before doing so. I wish to mention that the word "camber" appears to have been used in two different senses in two of the Papers. In Paper 18, half-way down page 76, the camber is expressed as 1 in 36 and from the diagram immediately above it is apparent that the word has been used as meaning a "side-slope". On the other hand in Paper 20, page 86, paragraph 5, the word "Camber" appears to have been used in the sense of the total rise at the crown of the road in relation to the total width of the road.

Col. Sopwith: No, Sir. I have used it only in the sense of a "side-slope" and not the rise of the crown in relation to the total width.

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* Paper No. 5 (*a*).

Chairman: It now appears that the word has been used in the same sense in both the papers. The American definition of "Camber" is the rise of the crown of the road in relation to the total width of the road. In view of the fact that the word is differently understood by different people it is better to make certain that we all mean the same thing when we use the word "Camber" in these discussions. Now we can continue the discussions.

Mr. R. H. Fitzherbert: I wish to know how to make the bullock cart keep away from the motor track. It is quite unlikely that you will get the bullock cart away from the motor track unless you employ a policeman. Bullock carts will always tend to keep to the top of the "camber". That is the only question I wish to ask.

Mr. T. Lokanathan: I wish to say a few words in discussion of paper No. 18 on important tourist lines, by my friend Mr. V. S. Srinivasaraghava Achariar. He has recommended the use of asphalt emulsions, Spramex and Colas. On enquiring from him, I find he has used them on a stretch about 1 mile 4 furlongs, another about 5 furlongs and another on a bridge, in all, at the utmost, about 3 miles as against between 600 to 800 miles of metalled road under his control in his District. What about the remaining 99½ per cent. of road mileage still remaining as waterbound macadam? Again from a perusal of the papers for the session and from the discussions which took place this morning, one is apt to be given the idea that we are keen on other things than waterbound macadam. So I wish to say a few words in connection with waterbound macadam. From my experience of the district roads, I find that the bullock carts and motor cars using the same roads start working against the road at cross purposes. While the motor car impact makes transverse undulations on the road, the carts make two longitudinal grooves in the first instance, and later desert these grooves for other parts of the road where fresh grooves are made.

In the years 1932—35 I set about trying to counteract these two cross purposes—I will tell you as briefly as possible my experiences. First, the longitudinal grooving due to the cart. How does it happen? When does it happen? How does it get augmented? How could it be prevented? These questions come up for solution. An examination of the grooved section was made. A stretch was broken up. The metal was found to come out rather easily and loose in the ridges of the corrugation. The metal was not found to have lost by wear but only smoothened in the corners and edges. The salvaged metal was hardly 40 per cent. the rest being earthy stuff which masqueraded as gravel when the macadam was laid There was a hard bed of old metal beneath 1 inch below the valleys of the corrugations. It was then clear that the damage to the surface and the change of its shape was due to attrition or movement of the metal. So far about the ragged old surface. The fresh surface was then watched to see when the wheel tracks developed. The wheel tracks were found to come in at the very outset after the spreading was opened to traffic when it was green and then got accentuated and fresh grooves were formed when the first ones became too deep for traffic. The usual explanation of the contractor and the maistry was that the wheel tracks formed on account of continuous passing of carts one after another in a string. Well, that explanation is all right, but then our road is after all for that cart traffic and it is to maintain the road in good condition under that traffic; that funds are placed at our disposal.

It is remarkable that such wheel rutting is not prominent on the same kind of water bound macadam near market places and in busy thoroughfares, say in municipalities or large towns while the wheel track becomes noticeable and more and more prominent as we go out on the high road. The obvious inference was that if we can distribute the traffic throughout the maintained width of the road as obtains in busy places enforced by the dense pedestrian impediment and also do consolidation so as to avoid attrition of metal our cart problem is solved. Next coming to the cart traffic with the internal combustion engine pounding away the working strokes causing great impact at stated intervals, our forward brothers of America have with their usual thoroughness investigated into this, taken slow motion photos of the passage of the motor car. The smoother the surface and the better the consolidation the untoward effect of the impact is less. The surface should be maintained smooth throughout the year and the binder retained in the interstices between metal.

If the dust nuisance, the only defect which such bituminous treatment of cheap variety can overcome, is insuperable, we may be justified in going in for costly treatment of the surface. Travelling frequently on the Grand Southern Trunk Road, when I was in Cuddalore during the heavy motor traffic seasons both in the X'mas seasons of three years and the Test Cricket match at Madras in 1934, which drew a large number of visitors to Madras, I found that by the simple expedience of permitting a speed friend overtake me and slowing down a bit. I was able to get along in my tourer car without suffering from the dust nuisance. It may be that we bewail the paucity of cars in our country as an indication of a low standard of living. Still, taking facts as they stand, I conclude that the dust nuisance is not yet become a great factor on our high roads. Municipalities and thickly populated towns do require a dust-free treatment.

So then no more apology, is, I think, needed to spend some thought on the water-bound macadam. Several engineers have found that the water-bound macadam is ruined by the combined traffic of the cart and the car—the former making longitudinal grooves and the latter making transverse undulations sucking up the binder and resulting in a salt-pan like formation with a loosened or broken up surface.

I will conclude by laying an emphasis on the points which I consider we must lay special emphasis on in our treatment of water-bound macadam surfaces to make it stand the dual traffic.

The selection of proper materials, good consolidation aimed at cutting out any tendency of the metal to move across the surface, avoidance of heavy camber, curing after spreading, obliteration of the wheel track for the first week after the spreading so as to keep the bullock off the beaten track, the provision of side-shoulders to spread out traffic on the full maintained width of road, and frequent blinding throughout the year are all important points for consideration. The binder that we use consists of about 80 per cent. mud. It gets in between the metals and is not found fit to hold the metal together. So we should make a good selection of the gravel used as binding material. The heavy camber which compels the cart traffic to keep to the crown of the road and avoid the edges where the carts take a tilt should also be avoided.

Mr. D. Macfarlane: I have a few remarks to offer on Paper No. 17. I congratulate Mr. Bashiram on having stressed the necessity for maintaining accurate and permanent records of work done on different road

surfaces and for collating at the same time the details of census of traffic intensities. At the same time I cannot help feeling that those of us who have experience of the vast number of forms, which have to be kept for the satisfaction of the Finance Department and the Accountant General, will view with alarm and despondency the introduction of any new and complicated form. Mr. Bashiram's form contains a considerable amount of information and in introducing his paper he has foreshadowed the inclusion of even more. It is obvious, therefore, that the volume of information to be included will tend to grow. The form as it stands is condensed into one sheet containing a record of over 10 years and it is a matter for wonder as to what the condition of that form will be when it has 8 or 9 years of information already entered. Without, wishing to deprecate in any way Mr. Bashiram's efforts to introduce procedure by which this valuable information will be kept on record, I suggest that it would be more convenient if it were compiled in a documentary form rather than in a series of restricted columns on one sheet of paper. Some years ago I introduced into the Punjab a Road Progress Diagram which included all items of road work in the way of reconsolidation and resurfacing. This form showed the amount to be done during the year, the amount done to date and the amount done in the previous month. This was for my own personal use and was kept in a single sheet for each circle, so that it could be glanced at easily while driving in a car, but owing to the keenness of various Officers, who all had personal ideas on the subject, the information which was added increased to such an extent that no Officer could use it intelligently while driving a car without the risk of running into a ditch (laughter).

It is an excellent idea to start the ball rolling as Mr. Bashiram has done so as to indicate the lines on which these important data can be recorded but at the same time we should be careful in asking our Junior Officers to keep such forms which owing to their complication may fall into disuse.

As regards the question of separate tracks for bullock carts and motor cars, the matter of primary importance is, to my mind, the dust nuisance, especially in the Punjab. Our Minister there has been pressing for a very long time for the construction of separate bullock cart tracks but financial stringency has prevented us from doing anything in this respect except in Lahore itself. It is, however, open to question if bullock cart tracks on the sides of roads are not more of a nuisance than an advantage. The point is that if these cart-tracks are not metalled, the dust from them will be wafted on to the traffic on the centre of the road and prove a great nuisance. On an ordinary road where the tarred surface is in the centre is it not better for the carts to make use of the middle of the road? It is a moot point. When there is a wind from the left side of the road and the cart track is on the left of the road it means a continuous fog of dust to the traffic using the crown of the road. If the carts were to use the middle of the road then one can overtake or pass on, the left or the right according to the direction of the wind and avoid the pall of dust.

Much as one would like to have these bullock cart tracks in places like the Punjab, my own idea is that it is better to do without them unless you can make those tracks dust proof by metalling them.

Mr. K. Rangaswamy Aiyer: With regard to the bifurcation of roads for motors and carts I wish to state my experience. On the Trichinopoly-Pudukotah Road the State had to maintain separate roads for bullock carts

and motor cars. The total length of road so maintained was 25 miles. There was a width of 40 feet with a central ridge in between, leaving an 18-foot track for cars on one side and an 18-foot track for carts on the other side. The difficulty experienced in maintaining the two sets of roads in good condition was that in order to make the car road passable almost all the allotment had to be spent on the car track thereby starving the cart track which therefore became intolerable. After 12 years this experiment was abandoned and now we maintain only one road. It is more economical to maintain this single road. While it is possible to maintain separate tracks for cars and carts over diversions, such as we saw in Mysore-Bangalore road a few days back, it is neither economical nor possible to keep the tracks separate over a long and continuous length.

Rai Bahadur Chuttan Lal: There is one point which is not quite clear to me in Mr. Bashiram's Paper. In paragraph 21 he says "so far we have considered only the statistical side of road maintenance and we can now proceed to deduce therefrom the main object underlying this paper and which gives it its name, namely, the economics of road maintenance with particular reference to proper control within reasonable limits of maintenance costs of metal roads. A study of a sufficient number of sheets similar to Sheet No. 3 should enable us to say which type of surface, in ascending order of higher specification, gives, economically speaking, the cheapest road for 100, 150, 200, 250 bullock carts per day".

In this Paper there is a great deal of useful information; but, when it comes to a question of cost, I find the only mention is about the annual maintenance costs per mile. What is not clear to me is how the annual average cost of maintenance will help us. For instance, if on a road, 50 miles long, one mile is, by way of experiment, treated with 'Tar premix' and the other with 'Bitumen Grouts' the average cost of maintenance of the road will not be affected, if one method of treatment is economical and the other is not. It seems to me essential that to study the economics of new methods of treatment, separate sheets giving full particulars of materials used, volume and nature of traffic, expenditure incurred, life of wearing surface, etc., should be kept.

Mr. T. Campbell Gray: There are one or two points in connexion with Papers Nos. 18 and 20 which I would like, if possible, both authors to assist us in understanding and perhaps help each other. They appear to be at variance as to what constitutes a sound water-bound macadam road. Page 76 of Paper 18, in the sixth line below the diagram, says "The consolidation of the metal should be stopped before it is 'thoroughly hard and smooth' and gravel binding should be added to the wet consolidation when it is three-quarters complete". Col. Sopwith, on the other hand, in his Paper (No. 20) page 87, para. 7, emphasises the point that "no admixture of earth or other substance should be allowed so long as really good road-making stone metal is available." Now is it not very necessary that we should at least agree as to what does represent sound water-bound macadam construction, before we proceed to discuss the advanced question of dual roads and surface treatment? It seems to me also that no water-bound macadam road can be worthy of the name that has in its composition particles,—we might say, soft particles—such as earth or gravel, etc. which separate the stones and allow them more or less free movement under the action of traffic. In short, is it not desirable to agree that a good macadam

road must be one in which sound mechanical interlocking of the metal is obtained and the voids only filled with binder? If this is agreed to, I think we should discuss these papers on that bearing.

In regard to Mr. Srinivasaraghava Achariar's suggestion for a dual purpose road, being closely associated with the roads in South India as District Board Engineer for the District of Chittoor, which contains some of the best roads in the Madras Presidency, it will be clear to him that two of the outstanding features regarding roads in South India are:—

(1) the available width of the roads is seldom more than 12 feet except in the vicinity of Madras and other large towns, and

(2) the cry all over the Presidency is to reduce maintenance costs and not to increase them.

I would like Mr. Srinivasaraghava Achariar kindly to furnish us with information in respect to the Table on page 81 of his Paper. He has proposed for roads carrying more than three to five hundred carts a day (presumably with a load of ¾ ton per cart) a cement concrete surface with a section of 6″-4″-6″. He has also stated that in the case of roads treated with two coats of surface dressing, the cost works out to Rs. 1,450 per mile per annum. I will be thankful to the author if he will tell us how he arrived at such a high figure.

Mr. S. G. Stubbs: In the concluding paragraph of Paper 20 (by Col. Sopwith) the author has taken exception to some observations made in my Paper No. 5 (*a*) read before the International and Indian Road Congresses last year. My remarks were based on the Punjab specifications for tarring which include the use of 1/5 gallon of tar per square yard for the first coating and 1/10 gallon per square yard for the second coating. Whereas Col. Sopwith recommends heavier applications than this. If heavier applications are made we will obviously get a longer life. Our policy in the Punjab is to cover up as large a milage of water bound macadam as quickly as possible in order to reduce maintenance costs. With heavier applications the rate of covering water bound miles with tar would have been very much less than it is at present, with the result that the standard of maintenance would have been a good deal lower that it has been during last 4 or 5 years. Col. Sopwith will however be interested to hear that subsequent experience has shown that where we have applied three or more coats of tar we can now count on getting two years' life.

As regards dual purpose roads described by Mr. Hughes there is another important point which strikes me, *viz.*, that if we had two sets of roads we should have to have two sets of bridges also. In an irrigation province like the Punjab this will be very expensive indeed owing to the numerous canals and water courses. If a dual set of bridges is not provided it will be necessary for bullock carts to be continually returning to the metalled road and once they get back to the metalled surface nothing short of an army of policemen will drive them off it again.

Mr. Campbell Grey raised a point saying that no earth should be used for binding the metal on water bound macadam roads. I entirely disagree with him. Besides adequate mechanical interlocking the voids in the water bound macadam surface should be filled up with earth and the only way to do this is to squeeze it up from the bottom. It is impossible to introduce it from the top.

Dewan Bahadur N. N. Ayyangar: From the discussion which we have had so far it seems to me that the best kind of road we can have is the dual purpose road for the mixed traffic of cars and carts. We have found that the ordinary water-bound macadam road will serve as the real dual purpose road. And, the best type of macadam road is what Mr. Gray recommended, namely, interlocked stone. I also agree with Mr. Stubbs when he says that the metal should be interlocked with earth.

With modern traffic the trouble is with the surface. We want a substance which will hold the surface and I think that Col. Sopwith has found a very good substance for this purpose, and that is tar. It penetrates well but the trouble is about the cost. It costs about Rs. 3,000 per mile. The nearest substance which will serve our purpose in place of tar and keep down costs is molasses (laughter) or some other similar cheap material. I invite Col. Sopwith to make his tar thinner so that it will cost only between Rs. 200 to Rs. 300 per year per mile. I invite research in this direction.

Mr. S. H. Lakshminarasappa (Government Architect, Mysore): I have had no experience in road-making. Regarding the dust nuisance, however, I have heard a lot of complaints. While roads are tarred to keep down the dust nuisance there are complaints from several quarters to the effect that tarring of roads proves injurious to the eyes. I should like to know whether any of the road-engineers have received similar complaints and whether anything has been done to counteract this complaint.

Mr. N. V. Modak: I only wish to make a few observations regarding the dual purpose for which roads are required to be constructed. We have to cater for both the bullock cart and motor car traffic. In Bombay, for instance, we have found it necessary in some cases to have on the same road two sorts of pavements, an asphalt covering over the centre of the road for motor cars and set-stone pavements on the sides for bullock carts. In the case of important roads we are trying the experiment of these two kinds of pavements. Which type to use on a particular road is settled after taking a traffic census to find out which type of traffic predominates on the particular road. All our roads which carry heavy bullock cart and lorry traffic, for example, the roads from the Harbour to the godowns, are treated entirely with set-stone pavements.

In our road programme we have estimated the life of the set-stone pavement as 15 years. Similarly we estimate that the sheet asphalt surface intended for motor cars will give a life of about 15 years. While some surfaces of the above mentioned type last longer than 15 years and some a little shorter than that period we find that on the whole our estimate of 15 years is correct and true.

Separation of traffic on the basis of the types of vehicles using the road is necessary. On one or two roads in Bombay experiments are being tried in this connection. It is however too early to say anything about it but we will be in a position to judge the result in about four years' time.

Mr. I. A. Templeton Shannon: Mr. Chairman and Gentlemen, there are two points in Col. Sopwith's interesting paper on which I would like to comment briefly. These are contained in the conclusions in paragraph 16.

The first is in connection with the traffic density limitations which have been taken for the various specifications. Upper limits of traffic intensity have been proposed in units of total tons per yard width per diem and this is in keeping, I believe, with international standards. I venture to suggest, however, that it is not in keeping with Indian traffic conditions where the most important factor, in South India at any rate, is the bullock cart.

I have known of several cases where roads have been treated with surface paint coats and their use suited to motor traffic. But when the roads have been opened to bullock cart traffic the wear of the surface was very greatly accentuated. I mention this to demonstrate that a data of traffic without details of the type of loads is not sufficiently revealing. I believe that there is a proposal to construct a test track at Delhi and I wonder if it would be possible to use this to correlate the difference in wear from bullock carts and pneumatic-tyred traffic. I feel that it is not until this has been done and some form of 'damage co-efficients' arrived at, that we shall be able to suggest traffic limits.

Mr. R. L. Sondhi: We are thankful to Mr. Bashiram for his interesting paper. A consistent record of all stages of road work is really necessary but it appears difficult to condense all information that is required into a single diagram and the lot of Sub-Divisional officers and Executive Engineers who may have to maintain these forms for each mile of road in their charge, would not be an enviable one.

As remarked by Rai Bahadur Chuttanlal the only reference to cost is about the annual maintenance cost per mile but it will not be possible to compare the relative economical values of different surfaces without introducing into the form the cost of construction of original road surface and its various stages, *viz.*, cost of soling road metal, bituminous materials, etc. This will surely swell the form to an unmanagable size.

Other important information needed for accurate determination of comparative values of different surfaces will be old surface, temperature during construction and during the year, rainfall during construction and yearly average cost and hoard of other information. This will make the form very cumbersome if the information is to be collected for each mile of every road.

The best way out will perhaps, be to either record this complete information only for typical mile or stretch of each type of surface or lay experimental surfaces and apply the conclusions arrived at from the detailed record of observations of such typical stretches or experiments in determining whether the different roads are being efficiently and properly maintained.

Chairman: Before calling on the authors of the papers to reply to the various questions raised, I should like to echo the note of warning given by Mr. Macfarlane about the danger of collecting statistics. I myself am rather too fond of statistics and on the last occasion when I thought that certain statistics would be of service in proving a certain point, I took the precaution of writing to some of the people from whom I was proposed to collect the information and who would have the trouble of compiling it and asked them in a confidential letter to state without any reservation as to what they thought of the proposals. They replied that the result likely to be attained did not warrant the labour involved. It

is obvious that there must be complete records of the roads and the traffic they carry. But as it usually takes a number of years to collect complete statistics over a wide area it is necessary before embarking on the compilation of statistics to be sure of continuance of policy and that the results to be gained justifies the labour involved.

We are running rather late on our programme and so I will not take up much more of your time. There is just one point I would like to mention and that is that in Burma we have the same system of maintenance as I presume is adopted in other provinces in India, *i.e.*, we have lumpsum grants. We do not have any maintenance or special repair estimates. A certain sum is budgeted for the maintenance of all roads and is allotted to various Executive Engineers. In our particular case, statistics do not help very much in spending the money because in recent years the money available is inadequate and remetalling, etc., cannot be done by rotation. The shortage of funds is accentuated by the system of construction by stages. Original works and maintenance are to a certain extent mixed up—A fact that has been recognised in a recent circular permitting original works on any particular road up to the extent of Rs. 10,000 to be charged to maintenance. With this system it is very difficult to say what is pure maintenance expenditure on the roads and to make a fair comparison of maintenance against traffic.

I will now call on the authors of the papers to reply to the points raised on their papers.

Mr. S. Bashiram: Sir, I find it rather difficult to answer the criticism levelled on my paper. The Chief Engineer of the Punjab finds the tables too complicated, while as the advance copy of the criticism so courteously sent to me, would show, they are not comprehensive enough for the Chief Engineer of the United Provinces. It is admitted on all hands that some sort of statistical information is necessary if we are to keep in touch with the behaviour of any treated or otherwise improved road surface. For this information to be of any use at all we must have details. We must obviously know the intensity of traffic; we must know as Mr. Sondhi said, the temperature or in other words the season during which a treatment was given. The temperatures at which various materials should be applied have been standardised and definitely laid down, but we find that the behaviour of applications varies according to whether they were given in the summer or the winter months. The information recommended to be tabulated by me is not based on the very exact methods that obtain in a laboratory but is necessarily confined to observations in the field. The statistics suggested to be tabulated in this paper are in the words of Mr. Mitchell's paper that will be presented to you later on "a record of qualitative and not quantitative experimental work". Unless you have information of what you are doing on a road and that in some detail, it is obviously impossible to deduce any results therefrom. If you are not going to have any statistics the choice is to revert to the old system whereby each executive engineer kept for his division merely a record of the year in which renewals were made. Conditions have become more complicated now and you cannot help your statistics also getting proportionately complicated.

My idea in presenting this paper was not to get you to accept the particular form suggested by me but as Mr. Macfarlane rightly interpreted it, simply to set the ball rolling in the right direction.

Mr. Chuttan Lal has unduly stressed on Form No. 2 which really was meant to give to the controlling officer an opportunity to see how his maintenance costs were going up. If during the course of a year some of his unmetalled miles have been metalled then there is bound to be some variation in costs. Supposing you started with a hundred miles of unmetalled and 500 of metalled road with a total expenditure on maintenance of Rs. 60,000, and next year owing to new construction your metalled milage goes up by 50 miles and the unmetalled milage is reduced correspondingly, you will have to interpret the new yearly maintenance cost in view of these changes. In other words, you have got to study these things rather intelligently and it is this probing that is required. The idea of sheet No. 2 is to bring pointedly to your attention whether the variation in costs is keeping pace with the change in traffic or other conditions on the road. If the traffic is going up obviously your maintenance cost will also go up.

Mr. Chuttan Lal kindly sent me an advance copy of the criticisms that he proposed to level. There is one point that he mentioned therein which has not been taken up today. I am bringing this forward to show how when you start on this game of collecting statistics you do not know where to end. He says in the advance copy that in the United Provinces they are not going to be content with average figures. They are going to collect figures mile by mile. He told me this morning that they have there 3,200 miles of metalled roads. In other words he is going to have 3,200 ledger accounts and there will be all these and various other details for every one of these 3,200 miles. Mr. Sondhi is already full of pity for the life of the sub-divisional officers and executive engineers who will have to compile the data as advocated by me, and we may assume that he will not be a candidate for transfer to the United Provinces under the circumstances.

The idea underlying my paper is simply to get started. If this form is not acceptable have some other but it is certain that the old system of recording in a register the year in which the road-surface was renewed will emphatically not do at the present time.

Mr. V. S. Srinivasaraghava Achariar: As regards some of the criticisms I wish to answer a few points. It was said that the cross camber 1 in 36 was too much. It is found to be quite all right in a 12 feet metalled road for single line traffic. Quite naturally the bandy-man is keeping to the road centre and when he sees the motor car he generally goes on the side and in doing so, damages much of the metal. That is why I suggest we should have the metalled surface sheltered at ends properly. It is the night bandy-man that generally keeps to the track and the day traffic does not keep to the centre. My suggestion for surface treatment was only in special traffic lines where we can afford finances and where there is absolute necessity. As I stressed in my paper and as Mr. Lokanathan suggested, there is very good scope for improving water-bound macadam roads and the best practice in South India is to consolidate with gravel only. We do not close the traffic when we are doing spreading. The best practice has been to re-roll the surface allow the traffic to go for some time, water the surface and re-roll it very slowly. Generally this planes all the defects and the surface so re-rolled, keeps better for any work. Sanding in such cases is done after the

second rolling. Re-rolling is generally done within a week and it does not cost much except for watering.

As for the other roads, I mean the *dual* roads which are becoming very prominent within about 30 miles from Madras, their width is very great and we can easily provide, on the embankments, a second class metalled road which costs about Rs. 300 per mile for maintenance. If we give metalled roads for the bandies, even though they may not be of the first class standard, there will not be much of dust nuisance for those who go on the asphalt road. I am somehow optimistic that the motorist will make his way and the slow moving bandies will keep to their side tracks.

Mr. Campbell Gray asked how I arrived at the figures. I have given figures that an ordinary water bound macadam road in this country costs about Rs. 600 per mile and the first coat lasts for about 3 years. I can furnish him details by correspondence.

Col. Sopwith: Chairman and Gentlemen, taking the points in the order in which they were raised I will reply to the remarks of Mr. Campbell and Mr. Stubbs together. I am afraid some of the wording of my paper, as pointed out by Mr. Mitchell, is somewhat loose. I prepared it in a great hurry. When I said that the metal should not be mixed with earth or other binder what I had in my mind was this. What happens in many places is that the metal is put on and immediately after rolling large quantities of earth or other binder are put on the top. Mention was made of this in para. 7 of my paper (page 87). If it is necessary for some reason to have more binder than exists in the old surface, I suggest that it is very much better as Mr. Stubbs pointed out to place the binder below the new metal rather than above it. Nothing should be put on the top until complete interlocking had been obtained by rolling. In connection with this point I have found travelling over the whole of the country that very different experience has been gained in various localities as to the amount of consolidation that can be done in a working day. My own experience in the Frontier is that a maximum of 800 c.ft. per day can be obtained. There is then no movement of the metal at all after consolidation.

As regards Mr. Stubbs' remarks about my paper, I entirely understood the necessity of the Punjab having to adopt very light coats. My only object in mentioning the point was that I have always personally held from the point of economy that it was very much better to use a heavier coat of Tar to be renewed at intervals longer than one year whereas the remarks was that the Tar manufacturers claimed that biennial renewals only would be required after 4 or 5 annual renewals. On my advocating the heavier coat to a high P. W. D. Engineer he told me that as a Tar manufacturer I was contradicting my own statement as referred to in Mr. Stubbs' paper.

Dewan Bahadur Ayyangar complains that the cost of tarring as compared with the cost of molasses is very high and states that Rs. 3,000 per mile is too much. He asked if the Tar could be made thinner to reduce the cost per unit area. It is impossible to thin Tar below the consistency of Crude Tar and Crude Tar is unsatisfactory for road treatment. The only method of thinning Tar is to make an emulsion of it. The use of an emulsion would increase penetration but decrease

the quantity of actual binder in the stone metal to a degree which would not effectively stabilise the stone metal if only one coat was applied. For this reason Tar emulsion has been found more suitable for priming soft laterite surface as a preliminary to the application of ordinary Road Tar painting.

Mr. Lakshminarasappa complained about eye trouble in connection with tarred roads. The Punjab and the Frontier have many hundreds of miles of tarred roads and I have never heard of any complaint of this sort so far and I am sure that I will be supported in this by the Punjab Engineers.

Mr. Lakshminarasappa: I was informed of this by a responsible officer in Madras. I will let you know the name* of the person.

Col. G. E. Sopwith: As regards the $1\frac{1}{2}$ inch carpet, referred to by Mr. Shannon, if the road is in sound condition but not absolutely even, it is usually desirable to construct a $1\frac{1}{2}''$ carpet in order that the minimum thickness in any portion may not be less than $1''$. Where, however, the road is in a sound condition and is quite even but has been consolidated too long to allow of efficient penetration if only painting is adopted it may be cheaper to apply a 1 inch carpet rather than to scarify and reconsolidate in order to ensure the necessary penetration. It is a matter of comparative cost.

Chairman: As much has been said about dual tracks, it might be of interest to mention the conditions in Burma. According to the Burma Highway Act, during certain months of the year carts must use the side berm of the road. An attempt to see that the provision of the Act was enforced, by the employment of road durwans, unfortunately led to the charge of bribery against these employees and they had to be dismissed.

Now another factor has arisen with the increased number of motor vehicles using the roads, bullock cart drivers prefer to use the track intended for them, so that their animals may not be startled by each passing vehicle and so on roads carrying considerable motor traffic the Act is being obeyed!

I will now ask you to pass a hearty vote of thanks to the authors of the papers for the trouble they have taken in preparing them.

The Congress adjourned for the day at 4 P.M., to meet again at 10-30 A.M., the next day, Friday, 10th January 1936.

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*Mr. Lakshminarasappa subsequently informed Col. Sopwith that it was the Engineer of the Madras Electric Supply Corporation and that he thought the incident occurred two or three years ago. Col. Sopwith has stated that throughout his experience he had not come across a complaint of the nature referred to.

Second Day, Friday, January 10, 1936.

GROUP 3: USE OF MOLASSES, VITRIFIED BRICKS AND CEMENT IN ROADS.

Chairman: Mr. S. G. Stubbs, O.B.E.

Chairman:—Gentlemen, before we start I wish to draw your attention to the business we transact to-day. We take up the papers falling under Groups 3 and 4. We first finish papers to the extent possible by 2 o'clock and then the Congress will adjourn. Then there will be a meeting of the Council followed by the Business Session at which all the elected members and the members representing business interests will attend. After that we shall go on with the remaining papers meant for the day.

Tomorrow morning we take up the remaining papers and finish with them.

The papers for discussion now are those in Group 3, *i.e.*, No. 19, No. 23 (c) and No. 25. I call upon Diwan Bahadur N. N. Ayyangar to introduce paper No. 19.

The following paper was then taken as read:—

Paper No. 19.

TREATMENT WITH MOLASSES OF THE BANGALORE-MYSORE ROAD

BY

Diwan Bahadur N. N. Ayyangar, B.A., L.C.E., M.I.E. (Ind.), I.S.E., Chief Engineer of Mysore.

The Bangalore-Mysore section of the Madras-Cannanore road which is about 86 miles long, has a heavy traffic of bullock carts, buses and motor cars. The annual grant for its maintenance is Rs. 36,700, or roughly Rs. 427 a mile. In addition, the grants for special repairs and from the Central Road Fund taken at an average for the last five years, amount to Rs. 24,000, or, about Rs. 300 per mile, thus bringing the total cost of maintenance to Rs. 727 per mile. The portions of the road from Bangalore to Bidadi, about 20 miles in length, and between Seringapatam and Mysore, about 10 miles in length, are subjected to intense wear and tear, as they form approaches to the large cities of Bangalore and Mysore. Efforts are continuously being made to keep them in order but the results have been disappointing. About two and a half miles at the Bangalore end and two and three-eighths of a mile at the Mysore end of the road have been asphalted at a cost of Rs. 21,000. This surface is

satisfactory but is not capable of standing the bullock cart traffic and expensive repairs have to be carried out periodically. Owing to the paucity of funds, it has been found impossible, in spite of urgent necessity, to extend the lengths of tarring or asphalting.

2. *Use of molasses.*—The idea of using *molasses* which is a by-product in the manufacture of sugar, as a cheap substitute for tar or spramex for surfacing roads was developed recently. It is a well known fact that in olden days, it was a practice in India to add jaggery water to lime resulting in an improved quality of mortar. At Mandya, in the Irwin Canal area of the recently developed project, there is a sugar factory and accumulated waste molasses is available on a fairly large scale and there are also quarries of lime stone, in fact, the lime for general construction in Bangalore and Mysore is mostly supplied from this area. Taking the cue from this old practice, a short length of the road surface formed of lime kankar was treated with *molasses* and the result was so encouraging that at present, about fifty miles of this road, the surface of which is composed of various kinds of metal such as granite, gneiss, dolerite, quartz, etc., is treated with molasses.

3. *Method of application.*—The old surface is swept of all loose dust by means of cocoanut fibre brooms so as to expose the interstices of the metal to a depth of about one-sixteenth to one-eighth of an inch, care being taken not to dislodge the consolidated metal. *Molasses* and water, mixed in the proportion of about 1:1, is applied over the cleaned metal portion either by hand or by means of a water lorry provided with a spraying attachment, the quantity of *molasses* required being about one and a quarter ton per furlong of 12 foot width. The mixture is spread out evenly over the surface and allowed to soak for half an hour after which, while it is still damp, coarse sand available in the "nalas" nearby is spread over the *molasses* and traffic is allowed to pass on the surface immediately. The process is both quick and easy. After a fortnight, the sand and *molasses* get worked thoroughly into the interstices by the traffic and the surface looks dark, somewhat like a tarred or asphalted surface.

4. The above method of surfacing roads only with molasses has been found to give a smooth and dustless surface in the dry season. Recently, however, there were heavy showers of rain at places, due to which some of the molasses got dissolved and spread out to the sides. Still there is a good portion of these left on the surface and it is expected that after the rains a renewal by a thinner solution of molasses will restore the surface to the required condition.

5. The cost of surfacing the road by the above process works out to about Rs. 140 to Rs. 160 per mile, for the first application (*vide* Statement I), the amount varying according to the distance from the sugar factory to the site of application.

6. *Treatment with molasses mixed with slaked lime.*—Experiments are now being conducted, to prevent the molasses from being washed out during rains, by mixing slaked lime with molasses before applying it to the surface. Molasses mixed with an equal bulk of well slaked lime produces a chemical union. The slaking of lime is easily done in a pit dug

by the road side or in a tub and the lime is allowed to slake at least for a day. An addition of a small quantity of charcoal powder will quicken the setting action, as it is said to give better aeration. The coarser the charcoal powder the quicker will be the setting action, which is also enhanced by the addition of a somewhat larger quantity of charcoal. The addition of burnt lime to molasses produces tri-calcium sucrate which is insoluble in water and therefore will not be washed out so easily during rains as the pure molasses would.

7. *Details of work.*—The road surface will have to be taken in half-widths. Barricading is easily arranged by placing empty drums along the centre of the road at intervals of about 15 or 20 feet. It is necessary to see that the road surface is properly formed before it is treated with the mixture.

8. The surface is first of all swept with cocoanut fibre brooms and palmyra brushes are then used to expose the interstices of the metal to a depth of about one-sixteenth to one-eighth of an inch. A priming coat of thin molasses, formed by mixing it with water in the proportion of about 1:4, is then applied over the cleaned portion, so as to soak into the interstices and keep the surface damp for the final coat to spread uniformly. For the final coat, the molasses is mixed with slaked lime and charcoal in the proportion of 1:1/2: 1/4 by volume. Each drum contains twenty-four buckets of molasses and to this quantity twelve buckets of well slaked lime in the form of a thick solution are added and to this mixture six buckets of charcoal are added and the whole well mixed immediately and then applied over the priming coat. About six drums or one and three-fifths of a ton of molasses: one and a half "candies", or three-eighths of a ton of lime; and two bags or 160 pounds of charcoal are required for each furlong. It takes about three to four hours for the final coat to set, and when it is still slightly yielding, coarse sand is spread over it and rolled either by a steam or ordinary road roller. The setting time varies according to the weather conditions—quicker during hotter days than during cold ones. After it is well set, the traffic is allowed on the next day.

9. A short length of the Bangalore-Mysore road in the 7th mile has been treated with the above process and the resulting surface is hard and smooth and is standing satisfactorily. There were four or five heavy showers also over this portion and hardly any wash-out of the molasses is observed. This method of surfacing costs about Rs. 300 per mile as per data of cost enclosed.

10. *General.*—The chief reason why *molasses* is so suitable for surfacing roads, is its hygroscopic and adhesive quality, that is, its power of absorbing water which helps to keep the road surface slightly moist, a property which is very important as it not only makes the road dustless but also keeps the surface intact without allowing it to break up and form pot-holes. The result of treating road surfaces with molasses mixed with slaked lime is very encouraging so far, and further experiments are even now being conducted to arrive at a correct proportion. It is suggested that wherever sugar factories exist, the roads round about such factories within a radius of, say, 100 miles could be dealt with economically on this basis with much benefit and satisfaction.

STATEMENT I.

Data of cost per mile for treating road surface with molasses.

	Rs.	a.	p.
1. Molasses 10 tons (at 1¼ tons per furlong), at Rs. 7/- per ton .	70	0	0
2. Cleaning surface and applying molasses, at Rs. 4/- per furlong . .	32	0	0
3. Sanding 3 cubic yards per furlong, at Re. 0-7-0 per cubic yard . .	10	8	0
4. Railway freight at concession rates and carting and other charges, Lump Sum.	25	0	0
5. Cost of other materials required, such as brushes, brooms, etc., Lump Sum.	2	0	0
Total .	139	8	0
or say	140 per mile.		

STATEMENT II.

Data of cost per mile for treating road surface with molasses mixed with slaked lime.

	Rs.	a.	p.
1. Molasses 5¾ drums, *i.e.*, 1·6 tons required per furlong at Rs. 7 per ton	11	4	0
2. Railway freight at concession rates and carting and other charges, Lump Sum.	6	0	0
3. Labour for cleaning road surface and supplying molasses, Lump Sum .	4	12	0
4. Lime ; 1½ candies, *i.e.*, 3/8th ton at Rs. 7/- per candy	10	8	0
5. Charcoal ; 2 bags—160 lbs. at 0-14-0 per bag	1	12	0
6. Sand ; 4 cubic yards at Re. 0-7-0 per cubic yard	1	12	0
7. Barricading ; light, etc., Lump Sum	2	0	0
Total per furlong .	38	0	0

Cost per mile $=38\times8=$ Rs. 304 or say Rs. 300.

N. B.—The actual quantities of materials required in the ratio of $1:\frac{1}{2}:\frac{1}{4}$ are as follows :—

(*a*) by volume :—

24 buckets of molasses ; equivalent to one drum full.
12 buckets of slaked lime.
6 buckets of charcoal powder.

(*b*) by weight :—

1 ton of molasses.
524 lbs. $=187\frac{1}{4}$ seers $=0$ 94 candy of lime.
100 lbs. of charcoal powder.

Note :—

1 Candy $=200$ seers $=\frac{1}{4}$ ton
1 bag $=80$ pounds.

STATEMENT III.

Statement showing traffic in both directions on the Madras-Cannanore road between Bangalore-Mysore section per day of 24 hours.

Serial No.	Number of vehicle.	Number of vehicle.	Average load in tons.	Total load in tons.	Width of metalled road.	Load in tons per yard of width per day.
1	Cars . . .	66	0·75	49·50	4 yards	75·52
2	Lorries . . .	21	4·00	84·00	"	
3	Buses . . .	20	3·00	60·00	"	
4	Bullock carts (empty)	91	0·25	22·75	"	
5	Bullock carts (loaded)	107	0·75	80·25	"	
6	Jutkas . . .	16	0·35	5·60	"	
				302·10		

Statement showing traffic in both directions on the above road per day of 24 hours during the Dusehra festival.

Serial No.	Name of vehicle.	Number of vehicle.	Average load in tons.	Total load in tons.	Width of metalled road.	Load in tons per yard of width per day.
1	Cars . . .	278	0·75	208·50	4 yards	174·25
2	Lorries . . .	50	4·00	200·00	"	
3	Buses . . .	20	3·00	60·00	"	
4	Bullock carts (empty)	139	0·25	34·75	"	
5	Bullock carts (loaded)	249	0·75	186·75	"	
6	Jutkas . . .	20	0·35	7·00	"	
				697·00		

Thus it is seen that the intensity of traffic will, during the "Dusehra season" lasting for about 10 days, be about two and a half times the normal traffic.

Diwan Bahadur N. N. Ayyangar. Mr. President and Gentlemen:—About the treatment of roads with molasses we have already had some discussion yesterday about its scope and its uses. As I said, the object of this treatment is to do something to protect the surface against the severe rasping and dislodging action of motor cars on the metal. I wish to remove one possible misunderstanding, and that by saying that it is not meant to displace asphalt treatment. It is meant only to supplement that treatment. And, as you know, we have thousands and thousands of miles of rural roads in India. So far as Municipal roads and approaches to towns are concerned, the only method of treatment is what is being done at present, *viz.*, the use of tar, asphalt or concrete on roads. But as regards rural roads if we have to wait till we are able to put up concrete roads or to tar them, I think we will be able to do nothing for very many years. I do not think we will become rich enough to take up such roads for very many years to come. We must therefore find the substitute which I have recommended. It is quite possible to do so wherever there are sugar factories within economic distance. It is not enough to use molasses only once; it may be necessary to do so more than once in fair weather. Even so, it will be economical. At Rs. 50 per mile, and using it 3 or 4 times in the year, *i.e.*, in the hot weather, the cost will come to only Rs. 200. If this substance is not available, we may have to look for some other substitute.

As for the method of using this, it has been found from actual experience that the surface dressing is likely to be more or less washed out by rain, not entirely, but to a certain extent. By experience we have found grouting satisfactory and durable. We spread the metal and water the road thoroughly. When rolling takes place, the soil works up from below and the whole surface becomes partly consolidated. There will still be open crevices between the metal. So we grout it with a mixture of molasses and a little lime and we add *some black substance* because we want it to look like tar. (Laughter.) We then spread sand and roll it thoroughly. We then put on more sand. That is the treatment which has been going on for some months.

There is one observation which I should like to repeat and emphasize and that is that wherever we have used molasses we are free from the nuisance of dust. Even if it is washed out and after the close of the rains if we go and examine, we see that though molasses has been washed out entirely and we still find the road much harder than the surface where it has not been used. That is a very important point to note. The treatment with molasses, therefore, is, an important improvement. Wherever there are sugar factories I say that the molasses which will be available cheaply is a great advantage and a great asset.

I hope you will be glad to discuss this paper on these lines and give the benefit of your experience.

The following paper was then taken as read:—

Paper No. 23 (c).

VITRIFIED BRICKS FOR SURFACING ROADS IN DELTAIC DISTRICTS.

By M. R. Ry. G. Gopala Acharya, Assistant Engineer, Madras Public Works Department.

1. *Introduction.*—The use of vitrified brick as a paving material has been well known for many centuries and their use as a surfacing material for roads in Europe and particularly in the United States has recently made rapid progress. There are Associations which have existed for the past thirty and more years to disseminate knowledge and to conduct research on the uses of vitrified bricks for roads.

2. Having had practical experience of road maintenance on the Ooty-Mettupalayam Ghat road, the Jeypore Ghat roads, and on the roads in the plains of Vizagapatam District Board, and having seen the deplorable conditions of roads in many deltaic districts, the writer believes that intensive study and research on the subject of road maintenance and construction in deltaic districts is now necessary in order to effect changes in materials and methods that will result in ultimate economy. In carrying out such research due consideration must be given to the materials locally obtainable if the most economical types for each case are to be discovered.

3. Just when bricks were first used as a paving material is lost in the historical obscurity of the pre-Budhistic era. There is evidence throughout this country of buildings, palaces, and temples paved with durable bricks. Between the years 1880 and 1920 vitrified bricks were manufactured at the Government Brick Fields at Chetpat, Madras, and they are doing excellent service to-day in the floors for stables of Veterinary dispensaries and Police quarters. Vitrified brick roads built in Holland during Napoleon's time are in service to-day. The service given by brick roads 30 or more years old in practically every city of the United States has been really remarkable. Some of these brick pavements were laid on natural soil without foundations or even adequate drainage. Nevertheless they represent a remarkable record of performance.

In deltaic districts where stone and gravel must come from long distances by rail and by road, the logical method of economic road development and maintenance is to use the natural deposits of clay and shale locally available by converting them into vitrified paving brick.

4. *Manufacturing process.*—For a proper understanding of the reasons for the durable qualities of modern vitrified brick a short description of the process of manufacture may be given. Manufacture of vitrified brick in up-to-date factories where there is laboratory control (as in cement factories) of all conditions, guarantees a product that is uniform and satisfactory. Clay or shale of the right physical and chemical composition within comparatively narrow limits is required to produce a vitrified brick meeting present day requirements and specifications. It is crushed and then ground to dust by giant rollers. After being screened this fine

material is mixed with just enough water to develop its plasticity. It then goes through powerful press that compacts it under enormous pressure and forces it through a die determining two dimensions of the brick. This column of material is then automatically cut into brick of proper size. Warm air is used to evaporate much of the free water and render the brick hard enough to be piled in the kiln. Fires are started at first slowly until in five to eight days' time the temperature of the brick is brought up to the fusing point of the particles of clay or shale usually over 2,000° Fahrenheit. When proper point has been reached these particles coalesce and fuse, forming a solid homogeneous whole. The kilns are then allowed to cool slowly to anneal the brick. This insures toughness. A new material has been formed which is practically indestructible.

5. These bricks are tested by the "Rattler" wear test. In this test, as prescribed by the American Society for testing materials, the bricks are hammered by the sharp blows of a large iron shot tending to break and chip them and are shaken up with more than 200 smaller steel shot grinding all the corners, edges and faces of the loose brick. Only the strongest, most homogeneous and toughest bricks can withstand this test and those failing to satisfy this test are rejected as a paving material for roads. The testing machine itself as well as all the details of the test have been developed, standardised and accepted by highway engineers as a positive means of determining the quality of the material.

6 Modern design of vitrified brick roads.—(i) *Foundations.*—A brick pavement is essentially premanufactured and its construction consists of assembling the finished bricks that are produced at permanent plants. Brick pavements have been laid on various types of foundations both flexible and rigid. In the southern section of the United States, brick roads have very successfully laid on natural sand, crushed stone and gravel. In the northern parts brick pavements have given satisfactory service on water-bound macadam, bituminous macadam and well-drained gravel. Where surfacing is done with brick on an old surface as a foundation, any variation in the old surface may be corrected by levelling-up with water-bound macadam, bituminous binder or other suitable material. The "tolerance" allowed in surface finishing of base courses of all kinds in modern specifications is practically the same as for the surface of the pavement, *i.e.*, ¼-inch in 10 feet.

(ii) *Cushion or bedding course.*—The material which has been most frequently used for the cushion or bedding course is sand, a certain amount of loam being allowed. But many Engineers now oppose the use of sand as it seems to be safe only so long as it is damp. The bedding course should not be thicker than one inch and should preferably be ¾-inch. Cement mortar, while it forms a bed which will not flow into cracks in foundations nor shift, is not entirely satisfactory, because, it is too rigid and acts like an anvil with the traffic acting as a hammer. A development of recent years is the use of a mixture of sand and refined tar for the bedding course. Brick pavements built on a bedding course of 96 per cent. sand and 4 per cent. by weight of refined tar gave excellent results. In some localities, six to seven per cent. of bituminous material by volume has been satisfactory. This can be mixed in concrete mixers or asphalt plants. The striking off and preparing a uniform bed is of extreme importance in the laying and maintaining of a smooth brick

surface. The use of a long straight-edge or template on the finished cushion and the correcting of all unevenness in the bedding course before laying the brick has been found to be very helpful.

(*iii*) *Brick course.*—The depth of the brick course in modern design is less than was formerly used. Until comparatively recent years the minimum depth of the brick course was four inches and the bricks were laid on edge. Experiments conducted by the United States Bureau of Public Roads on a brick paved circular track showed that when properly supported, bricks down to 2½-inches in depth will withstand heavy traffic. The depth in most common use at present is three inches. The bricks are laid flat. This results in a most satisfactory surface and because of the fewer number of bricks and joints, and of the decreased depth, economy has resulted. The following are the sizes and types of bricks generally used:—

Plain wire-cut brick (vertical fibre, lugless)—
$8\frac{1}{2} \times 4 \times 3$ inches and $8\frac{1}{2} \times 4 \times 2\frac{1}{2}$ inches.

Re-pressed lug brick—
$8\frac{1}{2} \times 3\frac{1}{2} \times 4$ inches.

Wire-cut lug brick—
$8\frac{1}{2} \times 3\frac{1}{2} \times 3$ inches and $8\frac{1}{2} \times 3\frac{1}{2} \times 4$ inches.

Vertical fibre lug brick—
$8\frac{1}{2} \times 4 \times 3$ inches.

The tendency is towards increased use of a lug brick which insures positive and definite separation of the joints and permits more thorough penetration of the filler. A type of lug brick that is meeting with favour is the wire-cut brick (vertical fibre) with lugs. This differs from the wire-cut lug brick in that the wire-cut (instead of the die) side is on the surface. The wire-cut surface provides a better non-skid surface. The specifications for laying the brick pavement allow a "tolerance" in level in the finished surface of one-eighth inch in ten feet. There is no reason why a brick pavement should not be as smooth as any other of more costly type because the surface contour can readily be adjusted during construction and also later on after the pavement is under traffic.

(*iv*) *Filler.*—The filler most commonly used is a bituminous material—in a great majority of cases pure asphalt. The reason for the almost universal adoption of a bituminous or flexible material is that difficulties incidental to temperature changes, such as internal stresses occasioned by "blow-ups" and unsightly surface cracks are thereby eliminated. In addition, if properly used, the joints are sealed against moisture and the edge of the brick is protected. The trouble encountered on account of the use of unsatisfactory fillers has resulted in much study and research. The most serious trouble has been bleeding of the filler during hot weather and slipperiness of the surface caused by some of the filler remaining on the surface for a period of time after application. Coarse sand rolled into the surface immediately after the application of the filler has been found to be of considerable value in preventing slipperiness as it peels off the surface in better manner. The tendency seems to be in the use of harder fillers which hold their place satisfactorily. They do not soften enough to cause trouble and as they become brittle during cold weather

the excess peels off the surface. A sand asphalt mixture consisting of about 25 per cent. sand or fine stone aggregate has been used successfully in the cities of New Orleans and Jacksonville. The aggregate increases the stability of the filler and decreases its tendency to flow or bleed at high temperatures. It should be noted that both of these cities are located in the south of the United States at a latitude of 29° equal to that of Delhi.

(*v*) *Application of filler.*—Even with an ideal filler the results will be unsatisfactory if there is poor workmanship in its application. The asphalt filler should be heated sufficiently to insure full penetration of the joints without passing the danger point and a thermometer should be used in the heating kettle or tank. The filler should be scraped and forced into the joints with hand squeegees immediately it is applied to the surface of the brick. Asphalt that has cooled will congeal and will only partly penetrate into the joints which should be completely filled.

(*vi*) *Relaying and replacement.*—Vitrified paving brick that has been in use for as long as thirty years can be taken up and relaid with the worn surface down or at sides. Vitrified brick is unique in this respect as it has a great salvage value. Pavements that have been constructed of bricks reclaimed from old pavements have the appearance of new pavements and are striking illustrations of the long life of a properly manufactured vitrified brick. In towns and cities where countless excavations are made for laying, altering or repairing service mains such as water pipes, sewerage drains, electric conduits, etc., the brick units can be saved and re-used without waste after the trench is filled. Due to the ease of removal and replacement of brick, repair operations, in general, can be performed with facility and economy.

7. *Costs.*—At present vitrified bricks are not extensively manufactured in this country to permit of its use for roads. They are now manufactured by Messrs. Burn and Co. in their Raneegunge and other factories; and the tile factories situated in the Malabar Coast manufacture same on special orders as there is at present no regular market. Manufacture on an extensive scale requires extensive plant and machinery. Such plant located in one or more centres in each delta will reduce the cost to a considerable extent. A vitrified brick factory cannot pay if its activities are confined to such bricks only, because the market would be limited. Such a factory could produce stock and special bricks, paving and roofing tiles, and sanitary fittings of glazed stoneware. For the latter the market in the deltas is unlimited. At the Government brick fields at Chetpat vitrified bricks were manufactured with only one hand press and burnt in Hoeman's kiln. Most of these bricks were used for flooring stables, and they are still in serviceable condition.

8. The approximate cost for surfacing roads with vitrified bricks is given below per 100 square feet—

	Rs.	as.
Verified bricks, 415, at Rs. 20 per 1,000	8	5
Repairing old road surface and forming sand cushion ¾ inch thick	1	0
Laying bricks and filling with tar and sand mixture . .	3	8
Incidental and unforeseen charges	1	3
Total for 100 square feet .	14	0

At the rate of Rs. 14 per 100 square feet, surfacing a road of 12 feet width and one mile long would cost about Rs. 8,870. If the bricks cost Rs. 40 per 1,000, then the cost per 100 square feet will be Rs. 22 nearly and the cost per mile about Rs. 14,000.

9. A comparative study of the cost of various other types of road surfacings is published in a bulletin by the Concrete Association of India and an extract from same is given below:—

Cost per 100 square feet (approximate).

	Rs.	as.
(1) Cement concrete slab 4"—3"—4"	27	0
(2) Cement macadam road, 4" thick	23	4
(3) Cement grouted macadam, 4" thick	17	10
(4) Asphaltic concrete, 2" thick	29	12
(5) Bituminous grouted wearing coat, with sealing coat, grout 3"	26	10

10. *Durability and low maintenance*—(*i*) *Brick pavements* are long lived and because of the hard dense tough units of which the pavements are composed, have shown their ability to resist the abrasive action of heavy, concentrated and fast moving traffic. Like other well-burnt clay products, paving bricks are practically unaffected by climate. Although a vitrified brick road is smooth, it has sufficient variation in texture to provide a safe hold for motor tyres, steel treads of carts and bullock hoofs. A vitrified brick road will not absorb water or filthy deposits. It is sanitary, dustless and can be easily kept clean. It is immune from attacks of acids, alkalies, and oils. These properties also constitute the reasons for the low maintenance costs. The enduring qualities eliminate frequent and costly repairs. Brick pavements have been in service for twenty and more years with scarcely a brick having been disturbed.

(*ii*) Authentic data bearing on the durability, wearing qualities and low maintenance of brick pavements were published in "Highway Engineer and Contractor" for October 1931, an extract from which is given below:—

"The Connecticut Avenue experimental road was constructed by the United States Bureau of Public Roads during the years 1911, 1912 and 1913, and included a number of different types of road pavements. The total maintenance costs of the different types of road materials for the 18 years from 1913 to 1930 inclusive were as follows:—

Brick	12·65	cents per sq. yard.
Asphaltic concrete	17·03	,, ,,
Cement concrete	43·76	,, ,,
Bituminous macadam	51·38	,, ,,
Bituminous treated macadam	148·65	,, ,,

Commenting on the brick section, the Government report published during June 1930 states "The brick section, section 6, remains in excellent condition and shows little wear and no indication of failure due to the character of the surface."

(*iii*) Converting these figures into Rupees, the average cost of annual maintenance of the various types for a roadway 12 feet wide and one mile long would be:—

	Rs.
Brick	151
Asphaltic concrete	203
Cement concrete	523
Bituminous macadam	614
Bituminous treated macadam	1,775

These figures give a general idea of the relative maintenance costs of superior road surfacings.

11. *Conclusion.*—In view of the preceding paragraphs, which outline what I have in mind, I submit the following recommendations, as a start towards solving the problem of road construction and maintenance in deltaic districts:—

(*i*) Suitable stretches of a furlong or more in length to be selected in one town of each deltaic district where the present cost of maintenance of roads is prohibitive and where other superior types of road surfaces such as cement concrete and asphaltic concrete are laid as experiments.

(*ii*) Vitrified bricks to be obtained from existing factories and the stretches selected be laid with them strictly in conformity with the latest specifications on the subject. Before laying the bricks they should be examined by testing a few bricks by the "Rattler" wear test, so as to check their quality.

(*iii*) The initial cost of such experimental stretches and complete records of condition and maintenance costs to be maintained for a period of some years. Very valuable data will thus become available.

Mr. G. Gopala Acharya:—This paper given a brief description of a method of road improvement suitable for deltas, where the problem of dust and extravagant maintenance costs is now met by the use of tar asphalt and cement in combination with various quantities of granite metal. Granite metal is being brought from long distances for such use though natural deposits of clay are more easily available. Under such conditions, the logical method of economic road improvement would be to use the local deposits of clay by converting them into vitrified bricks.

A brief description of the manufacture of vitrified bricks is given in para. 4 of the Paper. The special mixtures of clay used in its manufacture are of a peculiar character. The clay should not melt and flow when exposed to an intense heat for a number of days in the kiln but has to fuse gradually and form vitreous combinations throughout while retaining its form. The original granulation of the clay has to be wholly lost by fusion which stops just short of melting the clay and forming glass.

Road surfaces laid with vitrified bricks will not require repairs for several years and are similar to stone block surfaces. Portions which settle should be taken up, the sand cushion re-formed all good blocks cleaned and turned over where possible broken bricks being replaced by new whole bricks. A short note on the durability and maintenance of such pavement as published in the Journal, "Highway Engineer and contractor", is given in para. 10 of the Paper.

Just as the use of tar, asphalt and cement for roads was introduced gradually into this country by starting work on experimental stretches after observing and studying their use on roads in other countries, similarly experiments carried out on the use of vitrified bricks for roads in towns in deltaic districts would give very valuable data on their utility and durability. If found satisfactory factories of clay products will spring up in various deltas just like the cement factories have in recent years. The cost of such experimental stretches carried out by using bricks brought from existing factories situated far away from the areas to be treated will bear no comparison with the probable cost of a pavement built of bricks manufactured in a factory situated in the deltaic area itself. With these few words I submit this Paper for the consideration of this Congress.

The following paper was next taken as read:—

Paper No. 25.

CEMENT BOUND ROADS.

BY

W. J. Turnbull, B.Sc., M.Inst.C.E.

NOTE.—This paper merely presents information on the development of an interesting type of reasonably cheap road which has certain merits in that it has all the simplicity of waterbound macadam construction.

At the last Indian Roads Congress certain comments were made by several of the delegates about the high initial cost of the cement concrete road, which made it prohibitive except for heavily trafficked sections. Material reduction however in the price of cement have now to a certain extent removed this objection.

2. In recent years adverse economic conditions in other countries have been an incentive to road engineers to investigate the possibilities of a cheaper road on the lines of grouting the coarse aggregate with portland cement mortar. This type of road, which is exceedingly popular in England and Australia and has recently been tried out in America, may be defined as rolled coarse aggregate held together by portland cement mortar. It is constructed by placing cement mortar, having the consistency of thick cream, over a layer of rolled aggregate of the specified thickness, usually 4 inches to 6 inches, in such a way that the mortar penetrates the voids and completely fills them. The grouted coarse aggregate is then consolidated by rolling and an even surface texture is obtained with a canvas belt. The result is a slab very much like concrete but containing a high percentage of coarse aggregate.

3. Nearly two decades ago, a very elementary type of concrete road was in vogue in the United States called the "Hassam pavement". It was made by placing a layer of broken stone, varying in size from 1¼ inches to 2½ inches, and rolled as in ordinary waterbound macadam construction to a finished thickness of about 4 inches. A mortar of one part of cement to three parts of sand was then poured over the stone, care being taken to agitate the mortar continuously to avoid segregation.

4. Rolling was continued during the pouring of the mortar to force it into the interstices of the stone. When the voids were filled a second course of broken stone, 2 inches thick, was laid. This was frequently of a superior quality to the lower course. This was grouted also but with a 1:2 mortar and then rolled. The final finish was by brooming and brushing into the surface a thick mortar composed of 1 part of cement, 1 part sand and 1 part broken trap, ⅜th of an inch in size. This type of road was very successful and the earlier sections now carrying heavy traffic have recently been re-surfaced with four inches of cement concrete in order to make them suitable for modern conditions.

5. Experiments were carried out in America about two years ago, in order to bring construction methods of the cement bound road up-to-date. The research consisted of investigations into the fundamentals of:—

(a) Kinds and sizes of aggregates.

(b) Penetrating and binding qualities of mortars.

(c) Subgrade treatments.

(d) Methods of compaction and curing as demonstrated by core borings and strength tests.

6. Brief details of the experimental road are as follows:—

(a) The sub-grade, a virgin soil was shaped and rolled.

(b) Side forms and bulkheads marking ends of sections were placed accurately.

(c) The coarse aggregate was spread by hand and then rolled.

(d) Mortar was mixed in a small concrete mixer and applied direct by means of a spout.

(e) The grouted stone was compacted and finished by:—

(1) Longitudinal tamping to reduce irregularities.

(2) Long handled float immediately following the tamper.

(3) Surface wiped longitudinally with sheet of canvas.

(4) Brooming as final finish.

Full details of the research are given in the Engineering News-Record of February 15, 1934. The following brief specifications were envolved as a result of the experiment.

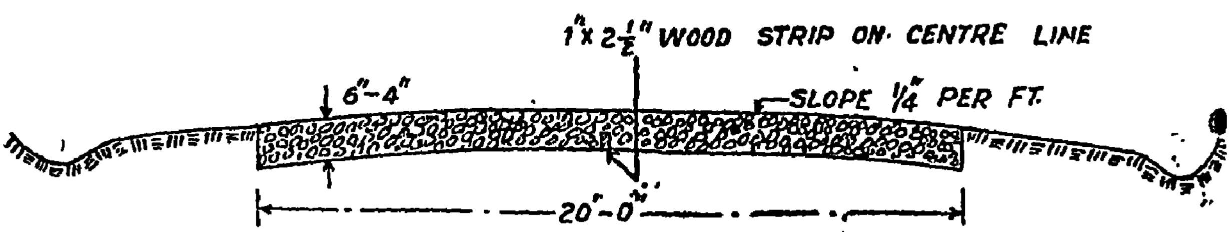


FIG. 1—CROSS SECTION FOR CEMENT GROUTED ROADS. A 6 INCH TO 4 INCH DEPENDING ON THE BASE OR SUBGRADE.

7. *Coarse Aggregate.*—Coarse aggregate shall be crushed stone. Not more than 5 per cent. shall pass a standard 1½ inches sieve, and not more than 10 per cent. shall be retained on a standard 2½ inches sieve. Small stone passing a 1½ inches mesh should be omitted as these will accumulate in the voids of the large stone and prevent penetration.

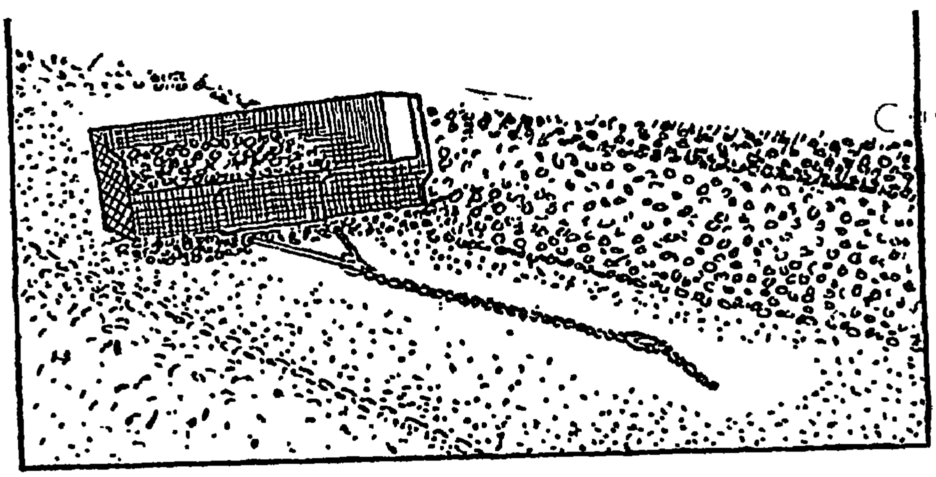


FIG. 2.—COARSE AGGREGATE IS SPREAD ON THE SUBGRADE BY A BOX WHICH LEAVES A LAYER OF THE PROPER THICKNESS; THE SPREADER BOX IS PULLED BY THE TRUCK WHICH BRINGS THE STONE.

8. *Fine Aggregate.*—Of the fines, 95 per cent. shall pass a number 8 sieve and not less than 10 per cent nor more than 30 per cent should pass a number 50 sieve.

9. *Subgrade.*—The subgrade shall have the grades shown on the plans. The surface of the subgrade shall not have inequalities exceeding ¾ inch when measured from a 16 feet straightedge. The subgrade shall be compacted with a roller weighing not less than 5 tons.

10. *Forms.*—Side forms shall be used. They shall have a height equal to the depth of the pavement and be strong enough to withstand the weight and pressure of rolling. Forms shall be firmly staked in place and shall not be removed until after the pavement has hardened.

11. *Joints.*—Where the width of the slab exceeds 16 feet a longitudinal dummy joint should be provided for by setting a 1 by 2½ inches wooden strip on the subgrade, along the centre line. The strip shall be set in a straight or evenly curved line with its 2½ inches edge vertical, and be firmly fastened in place so that it will not be disturbed by subsequent construction operations. Expansion joints, ⅜ inch wide, shall be put

in at 50 to 60 feet intervals. Expansion joints shall extend from top to bottom and edge to edge of slab and be free from obstruction of any kind.

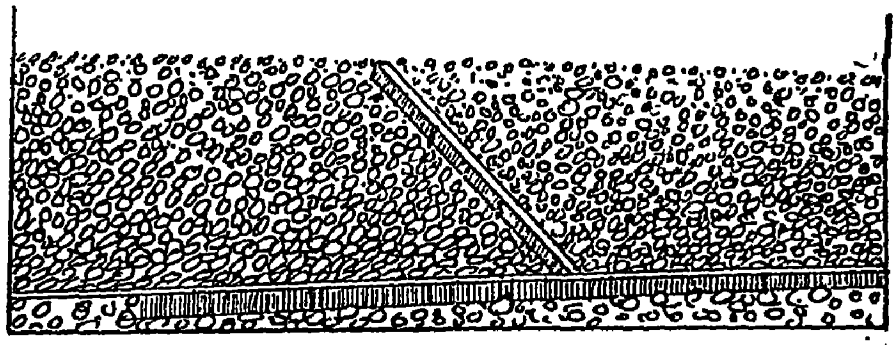


FIG. 3.—LONGITUDINAL AND TRANSVERSE CONTRACTION JOINTS OF THE INVERTED DUMMY TYPE MADE BY PINNING A 1 BY 2½ INCH WOODEN STRIP TO THE SUBGRADE.

12. *Placing and Rolling Course Aggregate.*—After the subgrade has been properly prepared the coarse aggregate shall be spread between the forms by an approved method to a depth which, after rolling will provide a thickness for penetration equal to that required for the finished pavement. The coarse aggregate shall be so handled that there will be no segregation of sizes nor any other variation in distribution and a uniform, even surface, having a slope from centre to sides of ¼th of an inch per foot, is secured. If any coarse aggregate becomes dirty or mixed with the subgrade or shoulder material it shall be removed and replaced with clean aggregate before grout is placed. Unless approved by the engineer, due to special conditions, only sufficient coarse aggregate for one day's grouting shall be in place at one time.

13. The loose, ungrouted aggregate shall be rolled with a tandem roller weighing not less than 5 nor more than 7 tons. Rolling shall be only sufficient to smooth the surface and no area shall be rolled more than twice. After rolling the surface shall be tested with a straightedge and inequalities corrected.

NOTE.—The object of rolling is to iron out the surface. In cement bound roads where critical stresses will be essentially tension, interlocking or "keying" of the aggregate is not important.

14. *Mortar.*—The mortar used in filling the voids in the coarse aggregate shall be proportioned 1 bag of cement to 2 cubic feet of sand, measured dry and rodded (approximately 2¼ cubic feet in the damp, loose, field condition) and sufficient water added to produce a mortar having the consistency of thick cream.

15. *Consistency.*—The consistency of the mortar shall be such that no separation of ingredients will occur and that voids in the rolled coarse aggregate will be completely filled. An excessive amount of free water coming to the surface will be evidence that too much mixing is being employed.

16. *Distributing Mortar.*—Regardless of mixing method, the mortar shall be deposited upon the coarse aggregate without segregation and in such a way that the coarse aggregate is not disturbed. Grouting operations should be continuous between joints or during each day's operation. The use of two or more light brooms for assisting mortar distribution will be required.

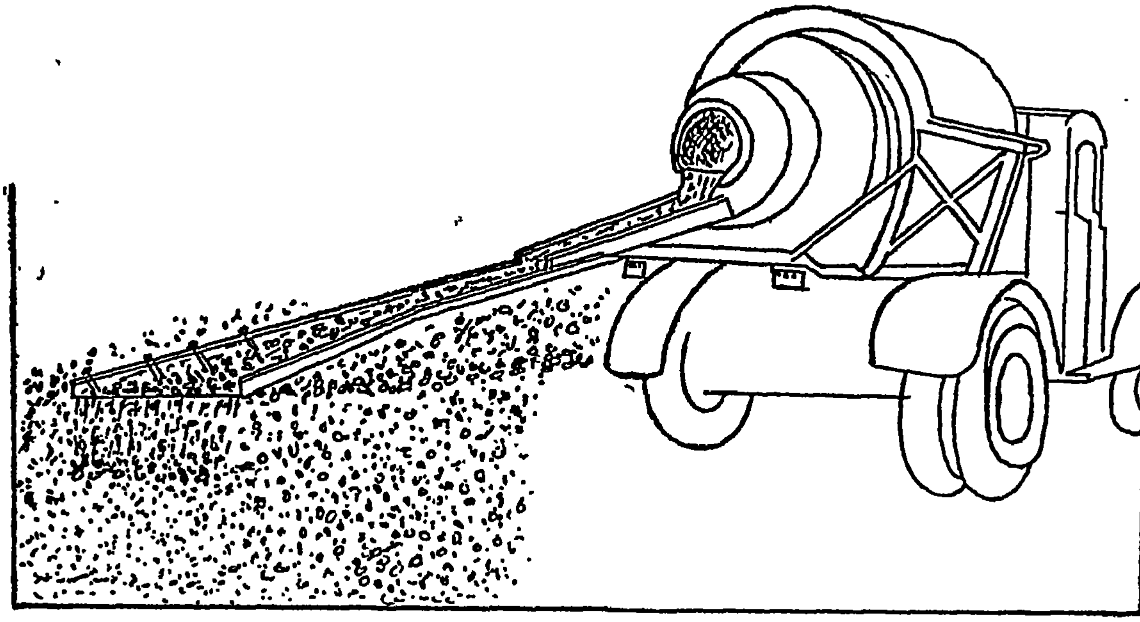


FIG. 4.—SOME TYPE OF DISTRIBUTOR IS REQUIRED TO CHECK THE VELOCITY OF THE GROUT AND PREVENT DISTURBANCE OF THE ROLLED COARSE AGGREGATE.

17. *Initial Mortar Rolling.*—As soon as a sufficient amount of mortar has been deposited (50 to 100 square yards), the grouted slab shall be immediately rolled with a tandem roller, weighing not less than 5 nor more than 7 tons, in order to facilitate complete penetration of the mortar. One rolling should be sufficient at this stage.

18. *Straightedging Surface.*—The grouted surface shall be straightedged immediately after the initial rolling and all irregularities greater than ¼ inch on a 16 feet straightedge shall be adjusted by proper use of stone forks while the grouted slab is still pliable (due to wet mortar). Should depressions occur which cannot be adjusted in this manner, then ¼ inch aggregate shall be added and thoroughly consolidated to give an even surface. If the straightedging and levelling work is done at the proper time, very little small stone will be required to adjust the surface.

19. *Final Mortar Rolling.*—At the proper time, determined by temperature and working conditions, the final rolling, with a 5 to 7 ton tandem roller, shall begin. Rolling shall continue and if necessary, additional mortar shall be added until an even, dense surface is obtained, but there should be a minimum accumulation of mortar above the surface of the coarse aggregate. The desired amount of surplus mortar is to be determined by trial and must be sufficient to provide for further settling into voids, to insure against projection of stone above the surface, and to allow an even surface finish.

20. *Finishing Surface.*—After the final rolling is completed, any excess mortar shall be evenly distributed over the surface. After an interval during which excess moisture is allowed to come to the surface, but before initial hardening begins, all excess mortar shall be swept or squeezed from the surface transversely, leaving only a very thin film of mortar over the coarse aggregate. This shall be carefully done, so as not to disturb the coarse aggregate.

21. *Wet Earth Cover.*—As soon as it can be done without damaging the concrete, the surface of the slab shall be covered with not less than 6 inches of earth. This cover shall be kept continuously wet by spraying for 10 days after the concrete is laid, and the surface may be cleaned off at the end of 15 to 20 days.

Mr. W. J. Turnbull:—Mr. Chairman and gentlemen:—Since writing this paper on cement bound roads I have collected some additional notes on the present practice in Germany and Australia in this type of road construction.

In this type of road it is desirable to use cement which does not set until the rolling is completed; frequently it takes about two hours to consolidate a section. It is also desirable that the concrete so produced should show less change of volume than ordinary premixed concrete, as the grouted road should have as few joints as possible.

The problem of manufacturing a special cement with delayed initial set, and with decreased expansion and contraction, was investigated in Germany about 5 or 6 years ago, and a new type of cement has now been evolved by means of a novel method of blending cement and bitumen. The product is marketed under the name of bituminized cement.

Bituminization is brought about by introducing particles of cement, distributed to an extremely fine degree, by blowing them by means of compressed air into an atmosphere of bitumen automized or vaporised also by compressed air.

In this bituminous atmosphere the bitumen finally precipitates itself as a very fine film on each particle of cement, without interfering with the granular structure of the cement. The amount of bitumen used is about 4 per cent.

It is claimed by the German Manufacturers that cement treated by the above method displays the following characteristics:—

1. The setting time can be delayed considerably.
2. The behaviour during hardening is considerably changed as compared with normal Portland Cement. During the early stages of hardening the volume change of bituminized cement is 50 per cent. less than normal cement.
3. The volume changes due to temperature are also much less as compared with normal cement.
4. The modulus of elasticity is lower than with normal cement. In other words bituminized cement is more elastic or less brittle.

This special cement is now extensively used in Germany and also America and the following notes have been taken from a description of a cement grouted road in Germany. They are of interest in that they indicate a difference in procedure to the American practice.

1. The existing waterbound macadam road was scarified, regraded and then consolidated with a heavy roller.
2. The base was then thoroughly moistened and on it was placed a layer of about ¾ inch of mortar of a fairly dry consistency and of 1:5 proportions.
3. On top of this, a layer of well moistened stone 1¼ to 2¼ inch size and about 3¼ inch thick was spread and rolled lightly.
4. This stone layer was then covered with a 1¼ inch layer of 1:4 mortar.
5. A second layer of stone 3¼ inch thick was then placed and rolled until the mortar penetrated upwards.
6. The surface was finished by brushing the mortar into any bare patches.
7. A final coat of mortar about ¼ inch thick and 1:3 proportions was then applied and covered with coarse chippings ¼ to ½ inch and rolled with a light hand or preferably tandem roller.

Longitudinal and transverse construction joints were provided, the latter at intervals of alternately 50 and 70 feet.

The above specification has been developed from the experience that the mortar frequently does not penetrate uniformly, resulting in honeycombing in the underside of the slab, and in order to avoid this, the thin layer of mortar is spread on the macadam base into which the first layer of stone is pressed.

German engineers attribute the success of their cement grouted roads to this bottom layer of mortar.

The final proportions of the above road works out to about 1: 4½: 8.

I believe the P. W. D. of the United Provinces laid a length of cement grouted road near Lucknow about 7 or 8 years ago. This cracked badly and was reconstructed by the addition of a 3 inch layer of ordinary cement concrete. Their experience and specification might be of use.

Recent practice in Australia on what they term roller consolidated concrete is of interest.

The material cost of the mortar in a normal (1: 2: 4) plain concrete road mixture is approximately 70 per cent. of the total material cost. It is therefore evident that substantial cost reductions can only be obtained by reducing the mortar content.

That this is possible without materially reducing the quality of the concrete can be seen by examining a core or section cut from normal concrete—1: 2: 4 mix or richer. Such cores invariably show that the particles of coarse aggregate are nowhere in contact with each other, but appear to be floating in the mortar matrix. A reduction of this apparent excess mortar content, however, renders the mixture unworkable and difficult to consolidate by normal methods.

Attempts to reduce the void content of the coarse aggregate, and thereby the amount of mortar necessary to fill them, by means of uniform grading is only partly successful, because, although the smaller particles tend to fill the voids between the larger ones, the saving of mortar thus effected is to a large extent counterbalanced by the extra mortar space provided by the pushing apart of the larger particles by medium or smaller size ones.

The lower limit mortar content is the amount required just to fill the voids in the coarse aggregate, and this limit can only be approached when either the coarse aggregate prior to grouting with or the premixed concrete is mechanically consolidated.

After a considerable amount of experimental work the Australian engineers have developed the following specification based on the above theory in which the proportions of the concrete are exceedingly lean, that is 1-2¼-9. The important clauses are as follows:—

OUTLINE SPECIFICATION.

Roller Consolidated Cement Concrete Pavement.

1. *Proportioning Concrete.*—Concrete will be proportioned by dry loose volume on the basis of one (1) part of cement, two and one quarter (2¼) parts of sand and nine (9) parts of coarse aggregate. The relative proportions of the various grades of coarse aggregate shall be determined with a view to obtaining a mixture of maximum density, but shall generally be four and one-half (4½) parts of ¾ inch gauge and four and one-half (4½) part of 1½ inch gauge.

2. *Mixing Concrete.*—The quantity of water used per batch shall be determined by the Engineer, but shall not exceed six (6) gallons per cubic foot of cement.

3. *Placing Concrete.*—The mixed concrete, after being deposited on the subgrade, shall be spread to a uniform depth for the entire width between side forms and the surface shall be struck off with a template to approximately two (2) inches above the final finished surface, so that after consolidation with a ten (10) ton roller, the finished surface will be true to grade and camber and flush with the top of the side forms.

The rolling of any bay or section shall commence as soon as practicable after placing, and the rolling of any batch must be completed within two (2) hours of placing.

Rolling must be longitudinal and shall continue from the edges towards the centre.

If it is desired to have an absolutely smooth surface the following procedure is adopted.

Before the base course concrete has set, apply a thin layer of concrete consisting of one part of cement, 2½ parts of sand, 3½ parts of graded coarse aggregate from ¼ inch to ½ inch and 5 gallons of water. This surfacing should be screened in the usual manner to produce the necessary surface finish. All other details will follow normal concrete road construction practice.

DISCUSSION ON PAPERS [Nos. 19, 23 (c) & 25.] in Group 3.

Mr. T. R. Ramaswami Aiyar:—Mr. Chairman and gentlemen, I wish to speak a few words about Paper No. 19. About the year 1912, in Tanjore District in which most of the Cauvery Delta lies, and where road metal is not available, an attempt was made to use this sort of stuff. Vitrified clay balls of about 1½ inches diameter were made and used instead of ordinary road metal but it did not serve for more than a year. This I just bring to your notice.

Recently in the case of a small diversion road which had to be formed for the construction of a culvert, where we could not get ordinary road metal we used vitrified bricks to a thickness of about 6 inches. That too did not serve for more than a month or two. I think that vitrified bricks, if used for road surfacing, should be prepared only after a detailed chemical examination of the quality of the clay used and also very great care seems to be necessary in the burning of the bricks.

I thank the writer of the paper for having given this suggestion. I think it has large possibilities and requires further trial, as there are a large number of roads where other metal could not be got; but good clay may be available in plenty. This arrangement might not prove to be a very cheap one for the reason that in the Deltaic tracts, fuel is very difficult to obtain.

Mr. D. Nilsson:—Mr. Chairman and gentlemen, I have seen some tests of grouted roads made in England. There they did not use any special type of cement but the ordinary cement grout was first passed through a colloidal mixer. A colloidal mixer is a type of mixer which mixes the cement and water more intimately than any ordinary concrete mixer. It forms a liquid which is more or less a colloid. The advantage of this is that the grout is so very much thinner as you can mix more water in it without affecting the strength.

The roads are made merely by laying down the stone, rolling it lightly and pouring in this grout. The grout flows in amidst the stones and definitely fills up all the voids between the stones without requiring any further rolling. The difficult point in Mr. Turnbull's paper is that he wants to roll the road after adding cement mortar, which appears to me rather a dangerous procedure. That, of course, has been overcome, as Mr. Turnbull says, by this new type of bituminous cement. However using a colloidal mixer is a very much simpler process and one avoids the second rolling. Grouted roads are cheaper than ordinary concrete roads. You save money on the stone as you have to handle it only once. The actual mixing of the cement mortar is simple and it is merely poured down and the road is finished. The roads made in England have so far proved entirely satisfactory.

Mr. Turnbull pointed out that the proportion of mortar, in an ordinary 1:2:4 mix. is larger than necessary; actually it is about 40 per cent. greater than the voids in the large aggregate. In making grouted roads, you only fill the voids with the result that you have got a very large saving on the proportion of mortar used. If you want you could use stronger mortar for the same price as the weaker but larger quantity of mortar in a 1:2:4 concrete. Having a smaller proportion of mortar the shrinkage is less. I am not a road man myself but I also understand that the larger

proportion of stone used will give a better wearing surface, it is a curious fact that you get a very constant strength from colloidally mixed mortar; even if you have the worst of labour you still get good concrete, and all the roads made were made with unskilled labour. and under bad weather conditions and have proved entirely satisfactory.

Mr. Shankar Rao Panje:—I have read with interest the first paper meant for discussion this morning on the treatment of roads with molasses. I request the author of the paper to supplement the information he has already given with some details of on the following points which evidently escaped his notice. These are—

(i) the specific gravity of the molasses or the degree of its consistency. This may be given in terms of the weight per gallon. Otherwise, there is the risk of adulterating the molasses supplied by a factory.

(ii) whether there is any limit of time within which molasses should be used after it leaves the factory in other words whether age has got any deleterious effect upon the quality of the molasses,

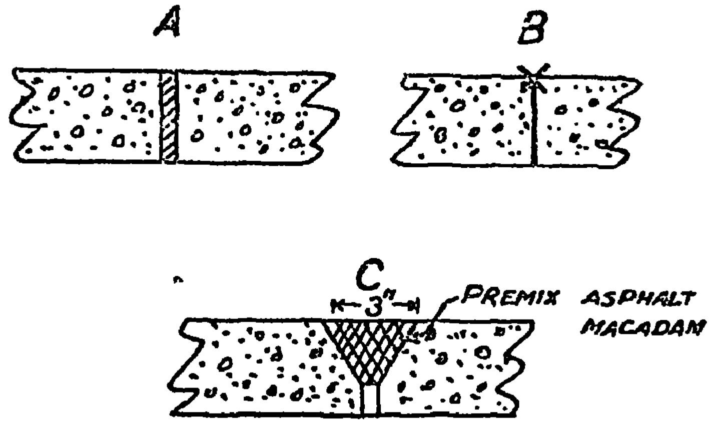
(iii) whether the lime should be used immediately after slaking or whether it can wait for a week or two after it is slaked.

Mr. A. Nagesvara Aiyar:—I wish to make a few general observations, with the experience obtained in connection with cement macadam roads in Cuddalore. The thickness of cement macadam was about 4 inches. Cement mortar of 1 : 2 proportion was laid between two layers of stone, $2\frac{1}{4}$ inches at the bottom and $2\frac{1}{4}$ inches at the top, the thickness of the cement mortar being $1\frac{1}{2}$ inches only, when dry. This was well rolled by addition of water, until the cement came to the top. It was done in 1930 and the total cost per mile worked out to Rs. 22,000. for a road way of 16 feet width. The total length done was only $3\frac{1}{2}$ furlongs. The cost of cement at that time was Rs. 60 per ton and granite metal that was used cost Rs. 26 per 100 cubic feet., as metal had to be borne by rail for a long distance. At the current rates of cement at Rs. 40 per ton and allowing the normal rate of Rs. 15 per 100 cubic feet per metal, the cost may come to Rs. 14,300. Allowing Rs. 15 for granite metal for metal coating. for mere macadam it will be Rs. 6,500. It is about 5 years since the work was done and the road has been under traffic ever since. The recent traffic census there showed that 1,800 carts are using the road daily on that stretch. Although it has been in continuous use for the past 5 years, it has not shown the slightest amount of wear and most probably it will last a considerable time longer. It was laid just in front of the sugar factory of Messrs. Parry & Co., at Nellikuppam in South Arcot District.

Diwan Bahadur N. N. Ayyangar:—I wish to speak a few words about cement concrete. We tried grouting of cement in the tracks on the road that you saw behind the Lal-Bagh, but we found that it could not stand and I gave it up as hopeless. The other suggestion of colloidal cement may be tried.

About cement concrete, one great difficulty seems to be about the joints. That seems to be the weakest point in cement concrete roads. It is necessary to allow for expansion and contraction due to changes of temperature and explore ways of overcoming that difficulty. What we generally do is as at sketch A *viz.*, to fill at the joint with a substance which is very hard and press it tight. After doing that I cannot

understand how it can allow for contraction and expansion subsequently. You may just as well fill it up with cement. It



JOINTS

is not like india-rubber at all, which is compressed and again expands when the pressure is released. The stuff we use is practically stone-hard. I think it is much better to build up a slab and put up the other slab, just abutting it as at Sketch **B**. Even then that point is one of weakness. It seems to me that a solution might be found in the way indicated as at Sketch **C**. You put up a slab so as to slope about 3 inches from the other slab and fill up the gap with shellmac and fill nothing at all between the two, lower down. That would make it more hopeful than anything else. I wish to suggest that this may be tried in any place where you make concrete roads.

Mr. H. E. Ormerod:—As I am not a technical man, I do not propose to touch upon the technical side of this question. I thought, however, that you might like to know that I had an opportunity in 1933 of seeing some of the bituminised cement roads in Germany which Mr. Turnbull referred to just now. In this connection I was very struck by the fact that they showed no signs of cracking after a year's use although they were subjected to all kinds of transport including 5-ton lorries pulling 5-ton trailers. Conditions there are not the same as in India but they are certainly very severe. Should you require any further information on the subject, it is quite easy to obtain it directly from Germany, or through us, or in any other way you think fit. The roads when I saw them were only a year old but conditions now will provide a better example of their ability to stand up to heavy wear and tear.

Diwan Bahadur N. N. Ayyangar:—Two points were raised in the course of the criticism, relating to molasses. In reply to them, I might say that the average specific gravity of molasses is 1:4 and the volume is 160 gallons per ton. As for lime, some lime is already in the molasses for when sugar is manufactured lime is added. But that lime has already combined chemically with the sugar. So I am afraid that that lime will not be available for hardening the molasses. We have to add a little of slaked lime. It is not necessary that the slaked lime should be fresh. If it is fresh, all the better. But any ordinary slaked lime, as we usually store for building purposes, may be used. Slaked lime powder is what we have found more effective. In the portion of the road between Bangalore and Mysore, about 43 miles on this side, in the Bangalore District things are done a little more elaborately: adding lime, grouting,

adding colour, etc. But on the other side, that is beyond the 43rd mile, there is no elaborate preparation made at all. You get the molasses from the factory, simply mix it with water in a certain proportion—latter it is about one-half of water to one of molasses and it is spread on the road. So far as I can judge, the work done on the side of Bangalore is better. On the other side it cakes up and the surface peels off. It does not stand the rain so well as the road on the Bangalore side. If, sometimes, excess of water is found to have been added to molasses, it can be rectified by adding more of fresh molasses.

As for the specific gravity being specified and other points raised in order to prevent adulteration by supplying factories, we get our molasses from our own Government factory so that we do not need all those precautions. They do not really want to sell molasses. They have other uses for it. We have to beg of them to give some molasses to us. If you purchase from private firms, naturally you have to have your own specifications and standards. We use the molasses as it comes from the factory. In the early days molasses used to be put aside as a waste product. It accumulated for about a year. When we thought of trying it as an experiment over a short length of the road near the Traveller's Bangalow at Mandya, it looked very hopeful. But when it was first applied it was such an awful mess. A mile or two of the road was spread with molasses, and when driving over it we, Mr Scaldwell and myself, thought that we had made a big mess of the whole job. To my great surprise, however, after 3 or 4 days, the whole road was smooth and dustless, as if it were a tarred road. That was the beginning of our venture.

If you want any more information, my local officers are here and they would be glad to give you everything.

Mr. T. R. Ramaswami Aiyar:—On the two points raised regarding the admixture of clay, a brief description of the manufacture is given in para. 4 of the paper. Such bricks are equal to granite stone, The cost of such bricks was Rs. 40 for 20,000, or Rs. 2 per thousand.

Mr. W. J. Turnbull:—Mr. Nilsson has briefly described the method of colloidal mixing, used by Messrs. Gammons, but I think he might have given us fuller details of this, as it appears to have certain possibilities in this class of work.

The question has been raised as to the period allowed for rolling, and doubt also expressed that the various operations could not be completed before the start of the initial set of the cement. The average time of the initial set of cements manufactured in India is about two hours and with reasonably efficient organization of the work, this is ample time to complete the rolling of a section of about 1,000 square feet.

Mr. Ramaswami Iyer has described his experience and success in the construction of a cement macadam road in his district. I would like to point out that this type of construction is not quite the same as the cement bound road described in my paper. In the cement macadam road a dry mixture of cement and sand is placed between two layers of stone, this is then moistened with the requisite quantity of water and rolled until the mortar appears on the surface, whereas in the cement bound type the entire thickness of stone is laid, grouted with cement mortar and then rolled.

Diwan Bahadur Ayyangar has touched on the question of joints in cement concrete roads. I admit that finality has not yet been attained

in the solution of this problem and investigations are being carried out in other countries. The joint sketched by him has certain weakness. A wide strip of soft material between the hard cement concrete slabs would, under traffic, form a depression and ultimately create impact. This in turn would cause abraison of the edges of the slab, even with the wide chamfer suggested. The suggestion could however be tried out but in order to be successful the surface of the asphalt joint would have to be exceedingly hard.

Mr. M. G. Banerjee:—Mr. Chairman and fellow delegates:—I just like to say one or two words about how to improve the bituminous surfacing on roads pavements etc., and also how to prevent cracks in concrete road surfacing. Some experiments have been carried out in England to produce adherent bituminous carpets, etc., on hard roads. The road is first coated with an oil of high boiling point with an admixture of either pitch, asphalt or other resinous materials. The admixture is necessary for thickening the oil to proper consistency. The thickened oil is then applied in the form of an emulsion. The dressing or carpet is then laid.

In case of concrete roads, generally we find that crack develops after a few months. To avoid such cracks, we usually provide expansion joints. The concrete is originally laid on the rough surface of the subgrade and it adheres to that surface and tremendous stress is induced at the time of expansion or contraction created by the difference in temperature and so though expansion gaps are provided, the free movement of the slab being checked, the expansion joints become ineffective and crack develops on the concrete surface. Moreover, this stress is likely to loosen the waterbound metal in the subgrade and weakens the foundation. To avoid this excessive frictional resistance between the slab and the subgrade it has been suggested to lay down strong paper on the road surface before placing the concrete. The paper must be so strong as not to tear even when wetted. To fulfil this desideratum the paper must stand certain tests. This experiment has been tried in Germany and may be tried in this country.

I take this opportunity of bringing before you the activities of the Corporation of Calcutta, to which I belong, with regard to the maintenance and improvements of the city roads in as few words as possible. The Corporation spends about 20 lakhs of rupees per annum in the upkeep of its roads. This includes Rs. 4,50,000 for bituminous treatment of the roads for which both tar and asphaltum of different viscosities and penetration (total 2,200 tons) are being used. Several experiments have been carried out in the past and are still being carried out with tar of different specifications and asphaltum of various penetrations ranging from 20 to 200, with concrete plain and reinforced and with all kinds of proprietory materials such as Bitumals, Colas, Colfix, Spramex, etc., and also with cold emulsions manufactured in our own plant. We have our own stone crushers, asphaltum concrete mixing plant, bitumen heaters, mechanical sprayers, etc. Cold emulsion was tried about six years back but had to be abandoned as not effective on the roads of Calcutta.

Hot laying is now being adopted in all cases and for pavements we always work on the principles of maximum density. Where traffic is light, painting and gritting with trap stone chips ranging from ¼ to ½ inch serve the purpose well. One coat of painting costs about 6 annas per square yard. In moderately heavy trafficked road ½ inch asphaltic concrete pavement is found to be enough and the maximum thickness is limited to 2

inches according to the degree in the density of traffic. Three inch bitumen concrete pavement, which was tried in the past, is not being laid at present as 2 inch thick pavement has been found from experience to be sufficient to stand up to very heavy traffic. It costs Rs. 2-6-0 per square yard. In commercial centres where there is an intensive traffic of both bullock carts and mechanical vehicles, *i.e.*, where the traffic is as high as 6,000 to 10,000 tons per day, stone setting is resorted to and this has given the best result. Mr. Chairman, I beg to thank you for giving me permission to say these few words before the delegates.

Chairman: Before thanking the authors of the three papers. I wish to make a few observations on them.

Paper No. 19.—There are two specifications given (1) using lime and charcoal costing about Rs. 300 a mile and (2) without using lime and charcoal costing Rs. 140 a mile. If two treatments are necessary annually, this will bring the cost of specification 1 to Rs. 600 per mile per annum. This figure does not fall far short of the cost of maintenance of a road painted with bitumen and tar. Presumably if the cost of maintenance is to be kept within the figure of Rs. 427 a mile, the 2nd specification will have to be used. Another point is that once molasses has been applied as a paint coat, it is very doubtful whether we can change over to ordinary tar and bitumen painting because tar and bitumen would not adhere to the surface. It would probably be wiser therefore to confine the treatment with molasses, to miles which are not good enough for bitumen or tar treatment, in order to keep them going until funds can be found for a more permanent method of treatment. As molasses is so cheap in this part of India, a more extensive use might be made of it for the purpose of stabilising the metal by introducing it in the body of the road rather than on the surface. This is apart from the surface treatment of molasses which for reasons already explained I do not advocate on new metalling unless the metalling is very cheap because it will be a waste of good metal.

Paper No. 23 (c).—As regards vitrified bricks, I think the whole question resolves itself to one of cost. If such bricks can be produced cheap enough, well and good, but I doubt this very much. Moreover the author himself admits that extensive plant will be needed and this will add considerably to the cost. Transportation is another important item. Owing to the high cost of the plant the number of manufacture centres can only be very limited hence the cost of transportation will still be high. In the Punjab we have succeeded in making roads with the burnt brick metal in conjunction with tar or bitumen. The chief feature of this specification is the laying of ¾ inch layer of hard chips on the surface in order to protect the bricks from crushing by bullock carts. As the amount of imported aggregate is small the total cost of transportation will not be very great.

Paper No. 25.—As regards the cement bound roads I am doubtful whether we can always count on obtaining good results with the methods proposed by the author. The chief difficulty about this type of work is the consolidation. Such failures that have taken place appear to have been due to the fact that the road roller is unable to properly consolidate right up to the end of a day's work.

In congratulating the authors on their most instructive and valuable papers I propose a vote of thanks to them for the trouble they have taken in writing them and to those who participated in the discussions.

SECOND DAY—(contd.)

Friday, January 10, 1936.

GROUP 4. RESEARCH AND EXPERIMENT.

CHAIRMAN:—Mr. S. G. Stubbs, O.B.E., I.S.E.

Chairman:—I call upon Mr. K. G. Mitchell to introduce his paper— No. 21.

The following paper was taken as read.

Paper No. 21.

GENERAL REVIEW OF THE RESULTS OF RECENT ROAD EXPERIMENTS IN INDIA AS REVEALED BY MODERN PRACTICE.

By

K. G. Mitchell, C.I.E., I.S.E., Consulting Engineer to the Government of India (Roads).

Object of Paper.

1. The art of road making is empirical. When we design a road bridge we adopt some conventional loading which we judge will cover all actual loaded conditions during the life of the bridge and we then apply the more or less exact if cautious theories of structural engineering. But in the design of road surfaces we are permitted no such aids or generous factors of safety. On the one hand the forces to be dealt with are more complex; the intensities of pressure under iron shod wheels, the impact of individual wheels, tyre action, and the disturbance caused by fast moving traffic are all important in their effect on a road surface and cannot be represented by any conventional loading. On the other hand there are except to some extent in the case of cement concrete, no rough and ready formulas giving the strength of road crusts and surfaces or relating them to different conditions of traffic, while the effect on foundations and sub-grade of the stresses applied at the surface depend on the condition and behaviour of the sub-grade about which insufficient is known. Consequently the design of road surfaces in relation to probable traffic is a matter of judgment founded on accumulated experience, which means experiment. In all empirical or "trial and error" sciences, earlier experiments are qualitative, that is they are designed to ascertain whether something will serve our purpose, or whether one thing will do so better than another, but as the science progresses experiment and research must become quantitative also. In our case this means that we must not only determine what specifications will serve in certain conditions, but, as exactly as we can, which of a variety available will ultimately exhaust as little as possible of our elusive ally, the rupee, in fighting our enemy, destructive traffic. Precise and quantitative experiment has another important aspect. It should enable us to prove not only what classes of traffic are most destructive—that we already know—but also the extent of damage in terms of money for which they are responsible so that we may

put before the community a clear statement of the bill which it is now paying for the privilege of abusing its property in roads by the use of destructive vehicles.

2. It is probable that in the whole of India, excluding Burma, there are about three hundred thousand miles of roads maintained by public authority of which some seventy five thousand miles are metalled or provided with some surface better than mother earth. The capital value of these at present prices is possibly about one hundred and fifty to two hundred crores of rupees; the annual maintenance bill about seven and a half crores, and the present annual expenditure on original works about two crores. These figures are of course approximate, but they suffice to show that with the advent of motor traffic it will not require a great increase in the cost of maintenance to swallow up the margin available for original works, *i.e.*, the improvement and strengthening of existing metalled roads or the provision of new ones; and, unless much more money is available, to arrest development. The financial depression from which India now appears to be recovering has had two main effects on this problem. It has curtailed funds available for roads, even for maintenance, and has resulted in some deterioration, but it has also given us a respite in the temporarily arrested development of motor transport. That respite however, appears to be now at an end as the following figures indicate.

TABLE I.

Imports of motor vehicles of all classes into India and Burma in recent years. (The figures are total numbers imported.)

Year.	Number.
1927-28	25,950
1928-29	34,159
1929-30	34,661
1930-31	23,015
1931-32	12,448
1932-33	9,659
1933-34	15,955
1934-35	24,981

TABLE II.

Consumption of petrol in India and Burma in recent years.

Year.	Millions of gallon.
1928	56·41 (Appro.)
1929	65·82
1930	73·53
1931	72·41
1932	69·79
1933	68·85
1934	72·45

3. Assuming that these figures of imports do not represent another false boom and allowing for the large replacement market, they warn us that the motor traffic that roads will have to carry is again going to increase. It is notorious that, in relation to other agricultural countries, the number of motor vehicles in use in India is, on the basis of population, extremely low. We must therefore be prepared for an increase in road motor traffic, an increase that all those responsible for roads must welcome

as proof of their greater utility and public value, but an increase which is likely to aggravate the difficulty of providing good roads at a reasonable cost in the peculiarly adverse circumstances of traffic and climate prevalent in India.

4. But even without this increasing burden on our roads it is suggested that the largely qualitative type of experiment with which we have been content in the past will no longer suffice and that efficiency and economy require a more precise and quantitative study. Proposals for the establishment of a test track and research station and in respect of the more uniform compilation of traffic statistics and the more precise recording of the details and circumstances of works of an experimental nature. are being placed before the Congress in the report of the Council and its technical sub-committee. It may therefore be of advantage at this stage to review briefly the results achieved by and the information derived from the qualitative experimental work which has so far been carried out in India as reflected in current practice. This review will necessarily be of a general nature, and for convenience the subject will be considered under various types of road although if stage development is accepted as the proper policy, many are inter-related.

Earth Roads.

5. Three quarters of the milage of roads maintained by public authority, and all village roads, are unmetalled. These roads carry the whole traffic of the countryside before it reaches a metalled road. They are therefore of vital importance and incidentally their general condition, which is deteriorating, militates against any improvement of the bullock cart as a road vehicle. It is a little illogical to point to the bullock cart as an archaic vehicle which has remained unimproved for centuries when the condition of its primary roads has probably deteriorated. The maintenance of unmetalled roads is starved of money. They are regarded as hopeless and in consequence the attempts to improve them have been spasmodic. The worst conditions are those of black cotton soil where traffic practically cannot move at all in the monsoon. Bad also are the conditions in the great alluvial plains because their density of population and of agriculture means more traffic; because the absence of hills permits heavy individual loads; and because, very often, the rainfall is scanty and may fail altogether. Where the alluvial deposit is very fine silt as in Sind the difficulties are greater still.

6. Experiments in the Punjab and North-West Frontier Province have consisted in a rough determination of the analysis of suitable soils followed by "grading". As regards soil analysis the following conclusions were arrived at by Mr. Stubbs in 1930 as a result of an extensive series of field tests[1].

"(1) A soil containing not more than 30 per cent. of sand and 70 per cent. of clay made a first class unmetalled road if properly maintained.

(2) A soil containing 30 to 40 per cent. of sand and the balance clay made a moderately good road but was liable to break up under heavy traffic.

[1] Progs. of Punjab Engineering Congress, Vol. XVIII 1930. Paper No. 137 "Earth Roads" by S. G. Stubbs.

(3) A soil containing over 40 per cent. of sand was of no practical value for roads and it was found necessary to blanket such soil with good earth to render it fit for traffic.

(4) Soil containing saltpetre was of two classes—

(a) where excess of salts were deposited on the surface due to capillary attraction and subsequent evaporation;

(b) where the soil was merely impregnated with salts.

The former soil is quite unsuitable for earth roads but can be treated in a similar way to Class (3) soil; the latter is excellent for earth roads, it tends to attract moisture, readily compacts and presents a hard surface.".

7. Mr. Breadon's[1] opinion is as follows:—

"Speaking generally from a constructional point of view there is hardly any soil which is wholly unsuitable for an earth road. It is, however, admitted that some soils are bad, but it is not difficult, nor is it costly, to improve the surface so as to make the road serviceable for motor vehicle and bullock carts.

(1) A clay-loam (containing about 60 to 70 per cent. of clay) makes a road which will stand up to heavy traffic.

(2) A light loamy soil (containing over 40 per cent. of sand) is not to be despised provided that it is graded and rolled when there is some moisture in the soil. This soil will easily carry moderately heavy traffic, but should it break up under heavy loads a 3 inches to 6 inches layer of clay spread over the surface at the time the second grading is being done will when rolled remove all difficulties.

(3) Soils impregnated with certain salts are about the best for earth roads, but

(4) where salts are in excess they can be remedied by either clay covering the surface or by spraying with the crudest of earth oil.".

8. The opinions of Messrs. Stubbs and Breadon closely coincide but they contrast remarkably with that of Col. Wakely.[2]

"The best proportions for the materials for an earth road are:—

Sand 70 to 85 per cent.

Silt 10 to 20 per cent.

Clay 5 to 10 per cent.

It will usually be sufficient to consider silt and clay together without separating them and a soil that contains 70 per cent. sand and 30 per cent. silt and clay would be a very good one, provided that the silt is not too much. This can be observed from the colour test and the slaking test.".

9. It is difficult to explain the wide difference between the opinion of Messrs. Stubbs and Breadon on the one hand and of Col. Wakely on the

[1] Progs. of the Inaugural Indian Roads Congress. Paper No. 3 "Earth Road Construction and maintenance by machinery" by G. W. Breadon—Para. 12, page 92.

[2] Progs. of the Inaugural Indian Roads Congress. Paper No. 4 "Earth Road Development and stabilisation by Gravel" By Lt.-Col. A. V. T. Wakely, Para. 26, page 74.

other, but all three have had considerable experience. Some of the difference may be due to the size and grading of the sand. If in Col. Wakely's case the sand is coarse, angular, and well graded it would be held in stability partly by mechanical interlock with a minimum of clay cement. The optimum composition advocated in the Punjab appears to be a clay sufficiently diluted with sand to reduce the changes of volume and bearing power due to variation of the water content. It seems that the study of soil must go deeper than mere field analysis of this sort and in the December 1935 issue of "*Indian Roads*" there appear certain articles on the more scientific treatment of the subject. It will be noticed that in Table G at page 27 an Al soil characterised in Table F (page 26) as "well graded and stable" has total sand 70 to 85 per cent., silt 10 to 20 per cent and clay 5 to 10 per cent. but that 45 to 60 per cent. is coarse sand 60 to 10 mesh. The sand in Punjab alluvium is presumably much finer than this.

Grading.

10. Given good soil, all authorities are agreed that the requirements are the maximum available width up to say 40 feet clear between drains; the minimum camber and height of bank consistent with avoidance of surface flooding—it is most rarely that damage is caused by capillarity from water in the side drains or on the haunches; and the minimum depth of drains to provide surface drainage. Grading can be done by manual labour or by machinery, the latter is the more efficient and economical for both first construction and maintenance.

Black cotton soil.

11. So far it appears that no treatment except gravelling has been found to improve the bearing properties of black cotton soil when wet. It has been stated that in Madras "no amount of sand can improve it as the soil never mixes with sand even for years."[1]

Prospects of earth road improvement.

12. The Punjab had at one time developed some 6,000 miles of improved earth roads, mostly in alluvial country, by mechanical grading. These roads are nearly all in charge of local bodies. At the outset their work and machinery were supervised by a special officer (the Engineer-Secretary to the Provincial Board of Communications) and his staff. Later these posts were retrenched and with the removal of that supervision the machines came to a standstill and the roads began to deteriorate. Moreover to some extent in the Punjab and to a very great extent in the N.-W. F. P. the improvement of these roads led to an increase in traffic to a total beyond their capacity and in the N.-W. F. P. most of the roads improved by Col. Wakely have had since to be strengthened by the addition of gravel.

Salt impregnation.

13. As pointed out by Messrs. Stubbs and Breadon there are certain conditions of impregnation of soils by salts that are most beneficial. The

[1] Progs. of First Indian Roads Congress. Daniel in discussion—Papers 3 and 4. Page 102, first para.

black *kalar* of parts of the Punjab and Sind provides a hard smooth surface capable of carrying considerable traffic so long as it is dry. When wet it is treacherous. The analysis of these soils in order to determine whether the conditions can be artificially produced is worth investigating. A certain amount of work of this nature has it is believed already been done in Sind but the results are not to hand.

Stabilisation of soils with bitumen.

14. Much research into the possibility of stabilising soils with bitumen in the form of cut backs or emulsions has been carried out in the United States of America and a few experiments have been made in India. It is possible that deep treatment of an exceptionally good and well graded granular soil might be satisfactory for all purposes, but with fine and ill graded soils the result appears to be adequate only for light motor transport and aerodrome runways but inadequate for bullock cart traffic which cuts it into deep ruts. If a soil so treated cannot be made to "set" again by watering and regrading and rolling, but requires fresh applications of bitumen, then the treatment will be too expensive.

Future of unmetalled roads.

15. The conclusion from work already done appears to be, unfortunately, that the development of traffic—and particularly bullock cart traffic—which follows upon the improvement of bad earth roads is such that the roads cannot be maintained in good order. The loaded bullock cart is the main cause of the damage. If the intensity is not great in relation to the width of the road then by re-grading once or twice a year, as rainfall renders this possible, the road can be maintained in tolerable order. But if the traffic is heavy in relation to the width of the road the whole is quickly cut into deep ruts. The conclusion appears to be that for certain intensities of traffic which may be quickly attained, an unmetalled road cannot be maintained in good order however good the soil.

Trackways.

16. It is for these reasons that the writer has for some time been advocating the use of "trackways" as cheaper than any other stage development. The idea is that if hard tracks can be provided to carry the loaded bullock cart then the rest of the traffic can be easily carried by an earth road having average good soil. The trackways if in cement concrete are expensive in first cost—say about Rs. 10,000 per mile—but it is believed that they will be cheap to maintain and on the whole be found to be economical. Doubts have been expressed whether the bullock cart will use and be able to keep on these tracks; whether the earth road against the trackways will not cut up badly leaving the tracks dangerously "proud"; whether in wet weather bullock carts may not get off the tracks and be bogged alongside; and whether the tracks will not be dangerous for fast traffic. As to the latter, the tracks will doubtless be used by all classes of traffic but they are not primarily intended for fast driven motor vehicles. For the rest, the experiments so far carried out in Assam, Bharatpur, the Punjab, Delhi, and elsewhere suggest that the trackways whether of stone

or concrete are proving satisfactory[1] although the attempts to inlay concrete with a more plastic surface such as a premix has so far not proved successful. The writer believes that in many conditions of traffic, costs of materials, and soil trackways will be a cheaper solution than any form of hard or metalled carriageway. They will not, of course, be so convenient for motor traffic as a metalled carriageway but if by their use the total milage of roads available to all classes of traffic can be added to, then they will be justified. What is now required in this field is further experiment to determine the cheapest form of trackway for various conditions. Stone slabs when available are excellent.

Waterbound macadam.

17. In order to deal with the formation of deep ruts due to bullock cart and other vehicles "tracking" but leaving the rest of the carriageway intact, various attempts have been made to provide hard or more durable trackways in macadam, of cement concrete, bituminous grouted macadam or premix. These do not appear to be satisfactory as uneven wear occurs at the edges. Stone slabs inlaid as tracks in the stone sett roadway over submersible bridges have long been used with success in various parts of India and are now being tried inlaid into waterbound macadam with some prospect of success. For the rest attention has been directed in recent years to the cheap renewal of macadam by the admixture of small quantities of new metal with the scarified surface[2] and to consolidation by laying the blinding material or "fines" below the metal, this method being peculiarly suitable if it is desired to obtain a dense crust with open surface for semi-grout or surface painting.

Surface treatments of macadam.

18. Surface treatment of water bound macadam has passed beyond the experimental stage. The available figures show that at the end of March 1930 there were altogether in the nine Governors' Provinces in India and in Burma about 1,400 miles of extra-municipal roads surface painted or sprayed with tar, bitumen, or asphalt. At the end of March 1934 the figure was 4,069 miles and it has since doubtless increased. The greatest milages at the end of 1934 were Punjab 1,665, N.-W. F. P. 529, United Provinces 511 and Bombay 487. The Punjab and the N.-W. F. P. have used mostly tar, the other two Provinces bitumen and asphalt. This class of work has been fully discussed at the First Roads Congress and in various issues of *Indian Roads*. There is still some controversy about the relative value of tar and bitumen and as regards the rate of application and the frequency of renewal necessary with tar coats. The writer would hazard the opinion that for the first coat at least tar is preferable and that the use of bitumen emulsions as first coats is unsatisfactory. Attempts to manufacture locally an emulsion of tar at Lahore failed but the writer has no knowledge of the results obtained with a certain proprietary emulsion.

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[1] "Indian Roads" No. VI, June 1935, page 7 and No. VII October 1935, page 14 *Vide* also Progs. of the Inaugural Indian Roads Congress, pages 48 to 50.

[2] "Indian Roads" March 1933, page 3.

It is clear that the use of surface paint coats as the next stage in development of water bound macadam is well established and that for the elucidation of certain of the points of controversy more precise and quantitative experiment is necessary. This he considers should be one of the earlier uses to which the test track should be put.

19. One point of interest may be mentioned. Where stone is expensive various experiments have been tried using vitrified brick usually as the aggregate in a grouted road but more rarely in water bound macadam subsequently surface painted. An example of the latter laid in November 1931 on the Lucknow-Cawnpore road is of interest. The length laid was one mile, a coat of 4½ inches of brick ballast was laid and consolidated on old macadam, 12 feet wide. It was then thoroughly cleaned and treated with 49 pounds per 100 square feet of Socony asphaltum (grade not stated) and about 2¼ cubic feet of 3/8ths to 1/8ths inch grit per 100 square feet. In 1933-34 it was repainted with approximately 46 lbs. of asphaltum and 3 cubic feet of grit per 100 square feet. The cost of the original work including the brick ballast and consolidation was Rs. 10-12-0 per 100 square feet and of renewal Rs. 3·2 per 100 square feet. The traffic is heavy. The surface has stood well.

20. Surface painting with tar-bitumen mixture is now being tried but it is too early to draw conclusions. The same applies to various uses of molasses particularly as the price of molasses is an uncertain factor.

Treatment of laterite surfaces.

21. Certain experiments carried out in Burma from December 1933 to February 1934 show that for light traffic it is satisfactory to surface paint a laterite surface with bitumen after a priming coat has been applied. The best primer was Burmah Oil Company's road oil, bitumen content 35 to 40 per cent. applied hot at the rate of 2·81 gallons per 100 square feet. This penetrated one quarter to three eighths of an inch into the laterite. Forty-eight hours later Spramex was applied at the rate of 2·93 gallons per 100 square feet and gritted with 2·67 cubic feet of gravel per 100 square feet. The cost was Rs. 4-6-0 per 100 square feet and the condition after 18 months excellent

22. Excellent results were also obtained with a 1½ inch bituminous carpet on laterite but the traffic at the site is not heavy enough to test this properly. The laterite surface was cleaned, shallow channels 6 inches wide and 1½ inches deep were dug along each side and diagonal channels 7 inches wide and 1½ inches deep were cut at about 3½ feet centre to centre to provide lateral and cross "key". The mixture was:—

Gravel	1 cubic feet
Sand	½ cubic feet.
Mexphalte 20/30	7½ pounds.

It was laid 1½ inch thick and consolidated with a six ton roller. The cost was 1½ inch carpet Rs. 10-9-0 and one inch carpet Rs. 8-6-0 per 100 square feet. No primer was used. The condition after 18 months was excellent and for light traffic no primer seems to be necessary. Scarifying laterite and grouting with an emulsion was not satisfactory.

Bituminous grout.

23. Ten years ago hot mix plants were so elaborate, expensive and unportable that premix was out of the question except in and near large cities with a concentrated demand for the output from the plant. Grouting was therefore used to a considerable extent. The introduction of cut backs for premix has provided an alternative and grout is now less used. Grouting is held by some to be an uncertain method but the failures that have occurred in India are usually attributable to an excess of bitumen resulting in too plastic a road, which is cut into ribbons by tracking bullock carts. An attempt made some years ago to economise and at the same time produce a more stable crust by grouting with a mastic of fine sand and bitumen was successful in two or three cases but failed in others. The difficulty of keeping the sand in suspension in a mastic of a consistency that could be poured appeared to be insuperable for large scale work and that particular method was abandoned. There are, however, many examples of successful grouted roads in India notably the Barrackpur Trunk Road (tar and pitch) and the Diamond Harbour road (Socony 101 and 105 in seal) near Calcutta and in the Punjab and elsewhere. The writer believes that as a general rule greater economy is now possible with premixes than with grout and that where heavy bullock cart traffic is able to track, undisturbed by other traffic, grouted crusts are more liable to yield than premix.

Light bituminous and tar carpets.

24. Carpets of one and one and a half inch thickness using tar or bitumen as the binder have been extensively used in recent years in Delhi and elsewhere with satisfactory results. For all but very heavy traffic these appear to provide a satisfactory method of dealing with old surface painted roads requiring something better, and may equally well be used, usually with a primer, on unpainted macadam if conditions are unsuitable to surface painting. Many of the carpets which have come under the writer's personal observation have not, however, been down long enough to enable any definite conclusions to be drawn as to their ultimate economic value.

Armour coats.

25. Another development of a comparatively recent date is the use of what are called armour coats which may be applied in conditions similar to those for which light bituminous entire carpets are suitable. Armour coats also appear to be likely to prove a satisfactory method of surfacing laterite, kankar, etc., where stone is expensive. Armour coats are usually constructed by priming the surface previously brought to camber with a tack coat, spreading coarse aggregate (1 inch to ¾ inch) at the rate of 12 cubic feet per 100 square feet, lightly rolling, sprinkling with water and applying quick setting emulsion at the rate of say 0·4 gallon per square yard (bitumen content 55 per cent.). The road is then left 12 hours after which it is lightly rolled and key stone (3/8 inch to 1/8 inch) spread at the rate of 2 to 3 cubic feet per 100 square feet. The key stone is then thoroughly broomed into position so as to fill up surface interstices and the second application of emulsion is made at the rate of 0·6 of a gallon

per square yard. After an interval of 12 hours this is lightly rolled and the final application of grit ($\frac{1}{4}$ inch to 10 mesh) is applied at the rate of $1\frac{1}{4}$ cubic feet per 100 square feet. This is then thoroughly broomed as before and the final rolling is then carried out until completion. The armour coats laid over a year ago in Delhi are so far doing well.

Heavy premixes.

26. Two and a half inch finished thickness appears to be the maximum now considered necessary for the heaviest type of bituminous or tar macadam or concrete in India. These are expensive costing in the neighbourhood of Rs. 20 per 100 square feet. They were fully described in various papers read at the Inaugural Indian Roads Congress and there are no particular points of importance, specially connected with them, which need be referred to here.

Concrete roads.

27. Cement concrete roads have generally been very successful and have stood up to heavy bullock cart and mixed traffic extremely well. Usually they have been laid over an old macadam base providing a very good foundation so that the question of deflection of the slab at joints has not arisen to the same extent as in the case of concrete pavements built on an earth sub-grade, or subjected, as in Great Britain, to extremely heavy lorry wheel loads. In these circumstances plain butt joints with some bitumastic filler appear to be adequate and these are usually at right angles to the centre line of the road. Oblique joints turning to a line at right angles to the road for the last two or three feet at either side so as to avoid a sharp corner have also been used with success. In general the lightest section so far used is probably one of 7-5-7 inch, but attention is now being directed to the possibility of much lighter sections in the interests of economy which, if successful, will expand the use of this material considerably.

28. Concrete has also been used with considerable success to provide special tracks or cartways at the sides of wide roads to carry bullock cart traffic, the centre being macadam surface painted or some light bituminous crust which suffices to carry all other traffic. The use of concrete in trackways on earth roads has already been referred to.

29. Cement macadam has generally not been successful.

Conclusions.

30. It will be seen that it has not been found possible in this Paper to attempt anything in the nature of a critical or comparative review of the results of experiments recently carried out or to arrive at any very definite conclusions. A study of the records available to the writer, of numerous experiments carried out in different parts of India has shown that in a large number of cases the information given is lacking in one or other important respect. Sometimes the quantities are not clearly stated, sometimes it is the particulars of the grade of bitumen used which are wanting; and in a very large number of cases there are no traffic statistics and practically in no case is there any reference to the maximum

and average load carried by bullock carts or the width of the tyres. In the absence of these and other particulars therefore it seems that, while a great deal of useful information has been obtained from these various experiments, it is still not possible with any degree of accuracy to compare the costs and the value of various specifications in different parts of India. The Technical Sub-Committee of the Congress has therefore drawn up a standard form* for the recording of particulars of all works whether experimental or otherwise which are likely to be required in years to come when the specification proves to have been useful or otherwise over a reasonable period. In particular the writer would emphasise the desirability of submitting the various stones used to such tests as can at present be carried out at the Government Test House at Alipore (the range of these tests will it is hoped be extended in future) so that full particulars may be available regarding the stone which after all is the material which ultimately carries the load in practically any form of road construction. It is hoped that the Congress will approve of some standard form for this purpose and also for the recording of traffic statistics and if this is done and these forms are regularly used it will then be possible to compare results with greater accuracy than it is at present.

31. The test track or test tracks have still to be established, but it is hoped that one at least will be working before very long. It appears to the writer that when this is done there will be less need for large scale experiments on the road. The test track will give, it is hoped, quick results bearing on the wearing properties of different specifications subjected to bullock cart traffic and that is what we principally require to know; because it can be said with some confidence that most of the specifications now used for surface treatments, premixes, etc., can adequately withstand ordinary pneumatic tyred motor traffic such as exists at present or is as far as can be seen likely to develop in the early future. But the increase in motor traffic, which must be anticipated, will render uneconomical a constantly greater milage of ordinary waterbound macadam and it is necessary to find the cheapest methods of improving that to carry motor transport and at the same time to stand the destructive bullock cart.

Mr. K. G. Mitchell:—I apologise for my paper which is of an extremely general and sketchy character. That being so, however, I do not wish to make detailed observations on it at any great length. I had so much difficulty in writing it that I almost gave it up. I have, however, placed it before you as I feel that it may be of interest as affording an indication of the two main difficulties experienced in studying the records of experimental road work.

The two main difficulties are, firstly, that it is extremely difficult to compile a complete and accurate record of all experiments heretofore carried out in India as the types of work vary between very wide extremes; and secondly, that it is very invidious and difficult, and might even bring one within the laws of libel and defamation, if one were to say too much about specifications and treatments which are too often described by trade names. These difficulties must be overcome in future. We have therefore recommended that the Congress should standardise the forms of record relating to the specifications, etc., and results of experiments. Such forms need not be very elaborate and they will serve their purpose if they merely bring to the notice of the person conducting the experiment the

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**Vide* Form at page 184.

points to be recorded by jotting down the figures instead of leaving each individual to think out for himself what figures are likely to be needed. I hope the Congress will adopt this recommendation and also eventually formulate certain specifications which will enable us to get away from trade names and specifications.

Regarding the recording of the results of our experimental work I wish to emphasise the importance of having the stone tested in the Test House at Alipore. We are all agreed that ultimately it is the stone that carries the load on the road. It is quite impossible to assess the values of different experiments unless at the same time we are in a position to assess scientifically the relative quality of the stones used. Unless we know more about a stone than what we can infer by merely looking at it and breaking it with a hammer we will not be in a position to judge its real strength and quality.

A large variety of stones has been tested in India. The pamphlet published by Dr. M. H. Krishnan, Assistant Director, Geological Survey of India, gives the results of the work carried out at the Alipore Test House and also a geological criticism of the nature of the different stones examined. You will find this publication* of very great interest.

I have only one other remark to make, namely, that the object, at present, of all our experiments is economy. One or two speakers during yesterday's discussions seemed to think that the improvement of surfaces must generally mean increased expenditure and was only aimed at the prevention of the dust nuisance. In fact, one speaker, if I understood him correctly, seemed to think that the dust nuisance so far as he was concerned could be avoided by his driving away from it and leaving a cloud of dust behind him, and that, therefore, there was no need to trouble ourselves too much on the score of dust! I agree that our principal aim is economy, but as has been pointed out in the course of the discussions, there is only one motor car for every 6,000 of the population in this country. Therefore we cannot rest content with looking after the convenience of the one person only. We should think of the other 5,999 also. So I suggest that even if, in some parts of India, water-bound macadam is so cheap that no stronger surface will be justified on the ground of economy, it is still necessary to adopt better surfacing at least on roads passing through villages so as to make motor transport less of a nuisance to the public at large.

The following paper was next taken as read:—

Paper No. 22.

ROAD RESEARCH AND RESULTS

BY

C. D. N. Meares.

1. *Foreword.*—This paper may be considered in some respects as a continuation of the writer's paper† on Test Tracks presented last year, at the Inaugural meeting of the Indian Road Congress. It goes one step

* Reproduced in "Indian Roads" No. IX, April 1936.

† Indian Roads Congress Paper No. 13.

further in describing research lines with a brief discussion of results and conclusions obtained so far. The writer has just completed a world tour devoted to the study of roads, and it would take not one Paper but a complete volume to describe the many activities of Research Specialists in the various countries visited. Road construction is daily approaching an era where it will be as nearly an exact science as any other branch of Engineering.

2. In a recent paper on Road Research, Mr. R. E. Stradling, C.B., M.C., D.Sc., M.Ins.C.E., Director of Road Research, Harmondsworth. stated:—

> "Road Engineering is becoming an applied science, and in the practice of any applied science two sides are obviously necessary: (1) the science; (2) the art. There will always be gaps in knowledge which must be jumped by the practitioner if he is going to carry through a job. This jumping ahead of knowledge is the art of road engineering. By carrying himself farther and farther by scientific knowledge he obtains better jumping-off points and probably realises more and more clearly what risks he faces in jumping and how best to guard against them."

There can be no truer summary. Both the Science and the Art are so utterly interdependent that it is obviously impossible for anyone to expect uniform results unless he is versed in both requirements. Yet I venture to say that in India we have many practitioners, familiar with the one without knowing a great deal about the other. You will notice that "The Science" is put first—no one can run before he can walk—and until we have a central road authority engaged in intensive road research, it is difficult to see how anyone in this country can learn the science *as applied to India*.

3. In order to give some idea of the ramifications of Road Research, I cannot do better than to draw attention to Fig. I, giving a chart of the tentative organization and programme of the Road Research Establishment of the Department of Scientific and Industrial Research, England. The sub-divisions shown in fainter type on the chart represent departments envisaged but not yet established, while the others indicate the lines along which investigations are already proceeding.

4. *Research in other countries.*—In every case Research may be divided into two main classifications:—(1) Laboratory Research, and (2) Practical Tests. It is with a view to providing a link between these two that Test Tracks have been developed. It appears a general opinion among Research Engineers, however, that the jump from the laboratory to a full sized track which reproduces as nearly as possible actual road conditions is too great and that some intermediate stage which will at least provide a preliminary basis of comparison cheaply and quickly is desirable.

5. For instance, in Java, the authorities have developed a portable testing machine which can either be put down on an existing road or on a small area specially laid for the purpose. The Java machine consists essentially of two wheels rotating freely on a common axle about 6 feet in length. This axle is pivoted at the centre to a post securely anchored to the road bed and provided with a prime mover which turns the axle round the central pivot, so the wheels follow each other in a 6 feet diameter circle. It is interesting to note that the machine was constructed

after the large Test Track at Bandoeng, as it was found that tests on the latter were comparatively expensive and it seemed desirable to have an intermediate link between it and the Laboratory.

6. At the Harmondsworth Research Station, there are no less than 3 testing machines which between them provide progressive links between the Laboratory and the road. The third of these machines is still in course of construction but the others have been in use (under the Ministry of Transport) for many years. A brief description of these machines is of interest.

No. 1 Machine is illustrated in Fig. II and consists of a revolving disk some 6 feet in diameter which carries the surface to be tested while the Test Wheel remains stationary. There are certain practical difficulties in operating this machine.

No. 2 Machine (Figs. III and IV) was developed as a result, and I believe it is well worth our while to consider a similar type for India, with or without a full sized track for the final testing.

For slow speed traffic No. 2 Machine has proved fairly satisfactory, but conditions in England have altered considerably during the last 20 years, and what is required now is a machine that can be run at sufficiently high speed to reproduce the fast traffic of today. Hence—

No. 3 Machine (Figs. V and VI) now in course of construction consisting of a captive lorry running on a circular track of approx. 110 feet in diameter.

Whichever machine is being operated, the results obtained have to be carefully correlated with known results under service conditions. The need of careful correlation is particularly stressed by the authorities at Harmondsworth. Without it there is a real danger of test results being taken too literally, with consequent hindrance to progress.

7. In America several Test Tracks have been built at various times. Some of these are full sized tracks on which lorries were operated by drivers under exactly similar but considerably intensified road conditions. Others were miniature tracks representing the first step out of the laboratory. One of the latter type constructed and operated by the National Crushed Stone Assn. may be of interest to us here in India. This testing machine consists of a circular concrete track fourteen feet in mean diameter on which the surfacing is laid, with a radial arm from the centre carrying the Test Wheel. The width of the Test surface is only eighteen inches; and rolling during construction is done by replacing the Test Wheel with a roll weighted to give varying pressures in terms of unit width. Pipes are bedded in the concrete base to permit of accurate temperature control. This type of track is cheap to construct, easy to maintain, permits of test under variable temperatures and has proven in every sense satisfactory. Operation would obviously be cheap compared to other types and after all, there is little point in laying a test surface many feet wide if only one or two feet of that width are to be subjected to traffic. The value of this machine is demonstrated by the following quotation from a letter received recently from the National Crushed Stone Assn.:—

"We feel that our circular Testing Track is the most useful laboratory testing device we have. With it we have been able to solve a large number of problems and the answer can be obtained generally within a few hours of operation."

8. I referred, in para. 3, to Fig. I illustrative of the scope and activities of Road Research. So far I have touched on one heading, and then only on one division of that heading. Those of you who have not already done so will certainly lose interest if I attempt to cover them all even with the briefest mention. Before going on to the other headings however, I would like to mention one other division under (III) of the chart which I think is an excellent illustration of the inventive ingenuity of personnel specializing in road research. I refer to the Skid machine (Figs. VII and VIII).

9. *The Skid Machine* is a motor cycle and side car combination with the side car wheel capable of being set at an angle to the motor cycle wheels and held in position through a dynamometer. By an ingenious device shown mounted in the side car in Fig. VIII the coefficient of friction or μ of the road surface is recorded direct on a chart. Tests are carried out under all sorts of climatic conditions and this machine has undoubtedly been the means of making English roads very much safer than they were a few years ago.

10. *Road Usage.*—In India we are concerned chiefly with that most destructive of all destructive traffic—the bullock cart. A considerable amount has already been done in the form of research to mitigate this nuisance and probably the answer lies in pneumatic tyres. As regards motor traffic I think we in India are lucky in that we have had remarkably successful results with the cheapest specifications, *e.g.*, surface painting types. One reason for this success is of course the cheap labour available which permits of cleaning and preparation of the road surface to a point undreamed of in other countries. We all know of instances where bituminous surface painting on waterbound roads followed by one or two repaints has stood up under motor and tonga traffic for 10 years or over and is still as smooth as the proverbial billiard table. Outside the principal towns our motor traffic is undoubtedly lighter than that in Europe or America but all the same I have found no figures in other countries to equal our results, and in this one respect India is probably ahead of those.

11. *Road Construction.*—Again referring to Fig. I, you will note the several divisions under this heading. In America practically every source of aggregate supply has been examined and classified according to its suitability for various types of construction. A powerful and efficient organization known as the National Crushed Stone Association is engaged in constant research with a view to ascertaining the most suitable aggregates, gradings and mixtures for various types of construction. Discoveries made by this Association as well as by other bodies have resulted in reducing the element of chance to an absolute minimum, even if they have not succeeded in eliminating it altogether. The Bureau of Soils has likewise classified soils so that the supporting value, resistance to moisture, etc., of sub-grades can be exactly calculated. In addition investigations made by the Bureau of Soils have permitted of the effective treatment of earth roads with bituminous carpetings for light traffic.

12. The manufacturers of Binders have their own Research Associations, and in the case of bitumens any way, practically every manufacturer maintains a large staff of research specialists. The Asphalt Institute correlates results and manufacturers' discoveries, develops methods of Test and issues standard specifications which hold good with minor modifications througout America. During the last decade the discoveries made by these bodies have revolutionized road construction, one example being the

general use today of cut-back asphalts. From small beginnings, cut-back asphalts are now some 75 per cent of the total market in Western U. S. A., exclusive of emulsions.

13. Similar conditions exist in Europe. Although the writer had kept as far as possible up to date with developments in other countries yet he could not but be amazed at the progress made during the last few years in scientific road construction. This progress rests on the firm foundation of road research, which has carried the "Science" to a point when the "art" can be easily acquired by those engaged in practical road construction.

14. *Developments.*—America is probably the most advanced country in the world as regards roads owing to the enormous growth of motor transport. Developments in America are of particular interest to us in India also, because their problems are much the same as ours, *i.e.*, vast distances to cover and severe climatic conditions to overcome. Temperatures of 115° in the shade are by no means uncommon in some parts of the American continent, and they have the added handicap of frost in winter. For these reasons I am confining a brief discussion of recent developments to those which have taken place in the United States.

15. Generally speaking then, the two countries India and America have much in common regarded from the Road Engineer's point of view. There is one great difference, however, and that is in the traffic, a difference which makes comparison difficult. Were it not for the ubiquitous bullock cart we could take results already achieved and adapt them with very little modification to meet our own conditions, thus getting more than half way towards our goal of applied science in one step. With pneumatic tyred bullock carts, however, and the increasing tendency to limit bullock cart traffic to certain roads, there is already a mass of information accumulated by research and experience in America which would have direct application in India and might even be intelligently interpreted to apply under bullock cart traffic also. For the sake of convenience I am dividing specifications into two types—surface treatments and premixed pavements.

16. *Surface Treatments.*—As already mentioned, the ordinary surface painting common all over India has given remarkable results. Considering this as standard, I believe that two other types, one lower and one higher, would be well worth our investigation out here. These are the so called oiled macadam and mat coat types.*

17. *Oiled Macadam* is simply a dust treatment which also effectively waterproofs and so prolongs the life of a waterbound road. In America labour is expensive and oil cheap, so it is common practice to use a thin asphaltic oil which penetrates the surface rather than to brush out and properly clean the surface. This oil is usually a medium curing cut-back containing 50 to 60 per cent. asphalt and is applied at the rate of approximately 3 to 4 gallons per 100 square feet with little or no blinding. The oil penetrates and then slowly hardens up by evaporation or selective absorption of the solvent, leaving a soft asphalt cement. Frequently this treatment alone is left for a year or so before being sealed.

18. Labour is cheap in India and oil expensive, so it is obviously to our advantage to modify American practice by using a far heavier oil (*i.e.*, one with a higher bitumen content) but less of it, and obtain penetration

*I hesitate to give these names as they are far from general, but seem to be the most descriptive.

by brushing out the road to a depth of half an inch, or so. Of course, having removed all the fines by brushing, we must replace them, and there is a productive field of research in determining what cheap local materials can be used, *e.g.*, sand, dust, cinders, brick dust, etc., and how effective such materials would be under a subsequent seal coat.

19. It seems reasonable to suppose that oiled macadam would stand up well under bullock cart traffic also, since it does not result in a mat but permits the stone to carry the traffic. Some experiments have already been carried out on these lines and results are sufficiently encouraging to warrant further research, particularly as many aspects of this treatment were not properly investigated at the time. For example, it has recently been proved that the affinity of any dust or sand for asphalt as opposed to its affinity for water is a most important factor, and a simple laboratory determination has now been devised. Oiled macadam would cost an average of Rs. 900 to Rs. 1,000 per mile in most parts of India, and it is quite feasible that some cheap retreatment annually or biannually costing about half the original outlay would suffice to preserve a smooth and dustless surface until some heavier treatment became justifiable. If this proves to be the case we should have a specification within the reach of all, and a few years should see every main road in India a motor road.

20. *Mat Coat* is the construction of a mat of appreciable thickness on the original surface, whether it be waterbound or already bituminous. The method is actually a mix-in place (now called Road mix), mixing being done by floating the cover coat to and fro by means of a drag and using a medium to fairly rapid curing cut-back or slow setting emulsion. A mat coat gives a very similar result to one inch Premix except that the mode of construction permits of progressive correction of surface irregularities by brooming, so that a remarkably smooth riding road results. American practice calls for a primer, but in India we can well omit that, and simply paint on about four gallons per hundred square feet of emulsion or cut-back. Three-fourths to a quarter of an inch aggregate is spread over this surface, and mixed thoroughly with a drag broom or pin-type mixing drag* until the chips are coated or at least present a dark "pepper and salt" appearance. After a suitable internal for setting, grit or sand is spread over the surface and broomed into the voids during rolling. A thin seal should be added after a few weeks under traffic. It will be seen that a mat coat is very similar to the surface painting familiar to all of us. It has the advantage, however, of permitting more aggregate to be taken up and preventing waste. There are no loose chips to be whipped off the surface and thus the final result is very similar to premix macadam.

21. Before passing on to premixes, I should like to mention the possibility of using a mat coat on *kankar* roads. Experience in the Punjab has shown that a one and half to two inches thickness of road metal rolled into a scarified *kankar* base gives excellent results. I would suggest going a step further and trying a thickness of only three quarters of an inch. Surface painting over *kankar* after proper priming has already proved a success under light traffic. I do not think that it would be difficult to develop a method of securely bonding a mat coat to *kankar*

*This is a flat metal platform with pins of adjustable length projecting from the underside. It is towed behind the roller automatically mixing and levelling the aggregate.

and so preventing wear of the *kankar* by water action and abrasion, while the mat coat should be sufficiently strong itself to withstand moderate bullock cart traffic. Such treatment if successful would cost less than Rs. 4,000 per mile of 12 feet road complete, and would go a long way towards solving the problem of low cost roads in the U. P. and elsewhere.

22. *Premixed Pavements.*—I have dwelt at some length on Surface Treatments as these are cheap and therefore of particular interest to us. Premix on the other hand is comparatively expensive and must for the present anyway be confined to roads in or adjacent to towns. Moreover, there has been little development recently in premixes other than improved design of mixtures and paving machines.

23. Plant mixes such as sheet asphalt, asphaltic concrete, etc., are prepared in large stationary plants and transported to the site of work in trucks. The use of finishing machines has become universal in America and results in exceptionally smooth pavements. These machines usually run on steel forms and consist of a spreader box in front, into which the mix is dumped and spread to the desired thickness across a given width of road. The mix is then raked by a revolving rake and struck off by an oscillating striker. Many machines have light rollers at the back to give initial compaction.

24. The general tendency is to use cold-laid plant mixes as these are easier to handle in every way. There are two types of cold mix, one in which the asphalt cut-back is heated and the stone dried or slightly heated, while the other is mixed and laid cold. Both types have their supporters and there is little to choose between the two.

25. One type of mixing plant recently produced is worthy of mention. This machine travels on caterpillar wheels along the road, picks up the aggregate from a windrow, dries, heats and mixes it with asphalt, discharging the mix at the far end.

26. Road mix types are becoming more and more popular in America, partly because of their cheapness. I am aware that the only trial carried out in India of road mix was not too successful, but this was probably due to the use of a comparatively slow-setting cut-back.* In this experiment the road did finally harden up and the natural conclusion is that successful results could be obtained by the use of a suitable binding material. One attraction of road mix types is that they permit of the use of the existing materials on the road, whether plain waterbound or surface treated. The usual practice is to scarify, examine the material so obtained by sieve analysis, and add aggregate of the required size to bring the mixture within the specified grading limits. The existing and added aggregates are then well mixed and spread ready for the first application of binder as shown in Fig. IX. Mixing is carried out by blading to and fro and use of the disc harrow. When every particle is coated the premix is spread out and rolled as shown in 4-5 of Fig. X.

27. The preceding paragraph describes the graded aggregate type of road mix, in which the aggregates are carefully graded from one and a half inches of metal down to and including 5 to 15 per cent. of dust, the grading being such that there is a minimum of voids and the percentage of bitumen regulated to fill these voids. This type is the most popular in America chiefly owing to the fact that suitable gravels are available in many places, and also because the high inherent stability of a "maximum

*See "Proceedings of the Inaugural Meeting of the Indian Road Congress" Vol. I, pages 34-35.

density" mix permits the use of a soft asphalt. Thus the pavement remains plastic and stands up well in localities when the temperature variations are high. It also has a high salvage value, as it can again easily be scarified, remixed with a little cut-back and relaid.

28. Where crushed stone is easily obtainable, it is usual to use the open graded type of road mix. In this case crushed stone or slag is used, and since stability depends on interlocking plus the action of the binder only, careful grading and a hard binder are necessary. The sequence of operations is shown in Fig. X. This type may be laid in either one or two courses, the latter being preferable.

29. I believe road mix types would repay further investigation, particularly for military purposes, aerodrome runways, and for application in areas where gravel formations are prevalent. Figures IX and X show the whole work being done by machinery, but a great deal could be done by hand, using locally manufactured adaptions and/or bullock traction.

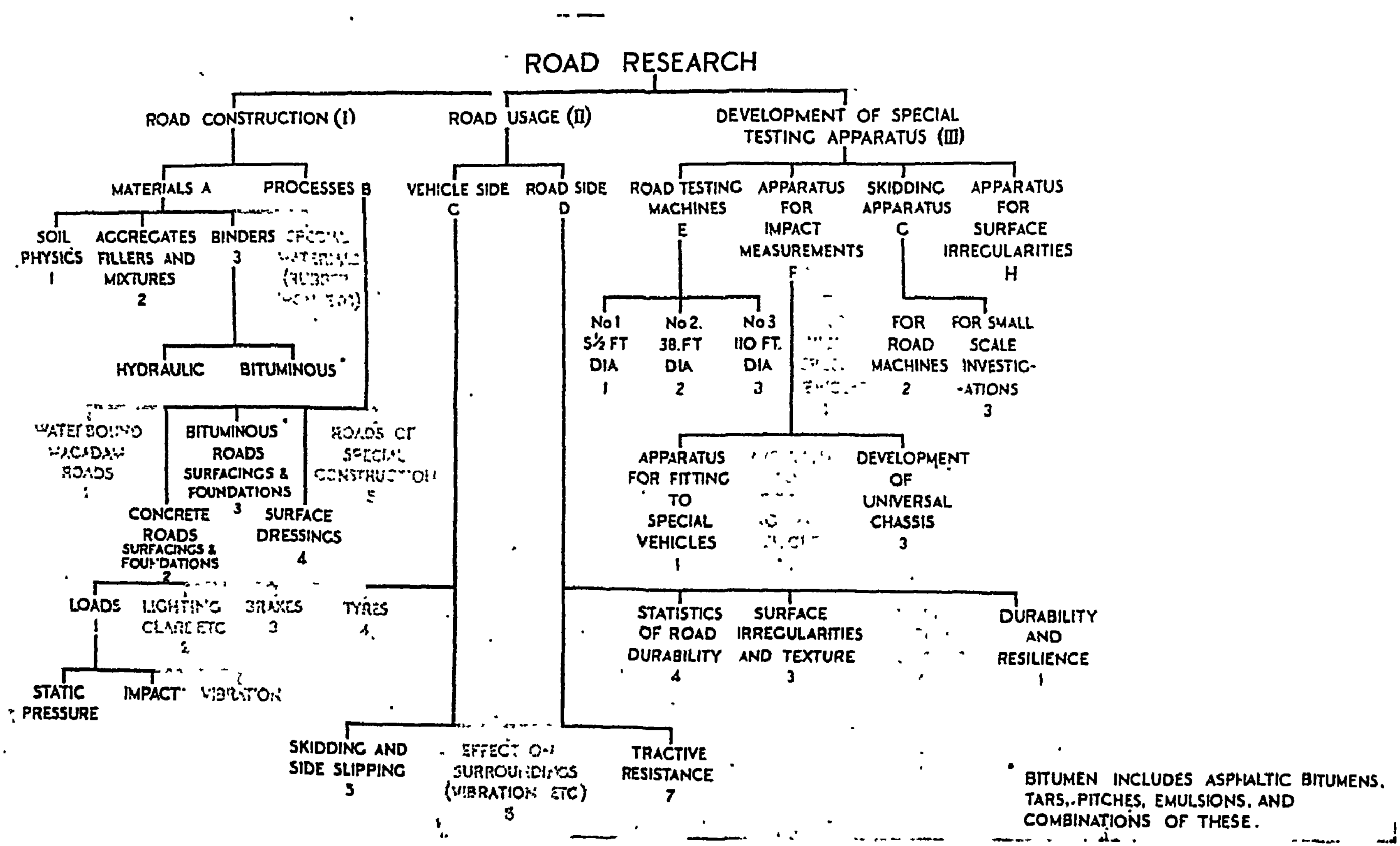

Fig. I Chart showing programme of Road Research followed at Harmondsworth.

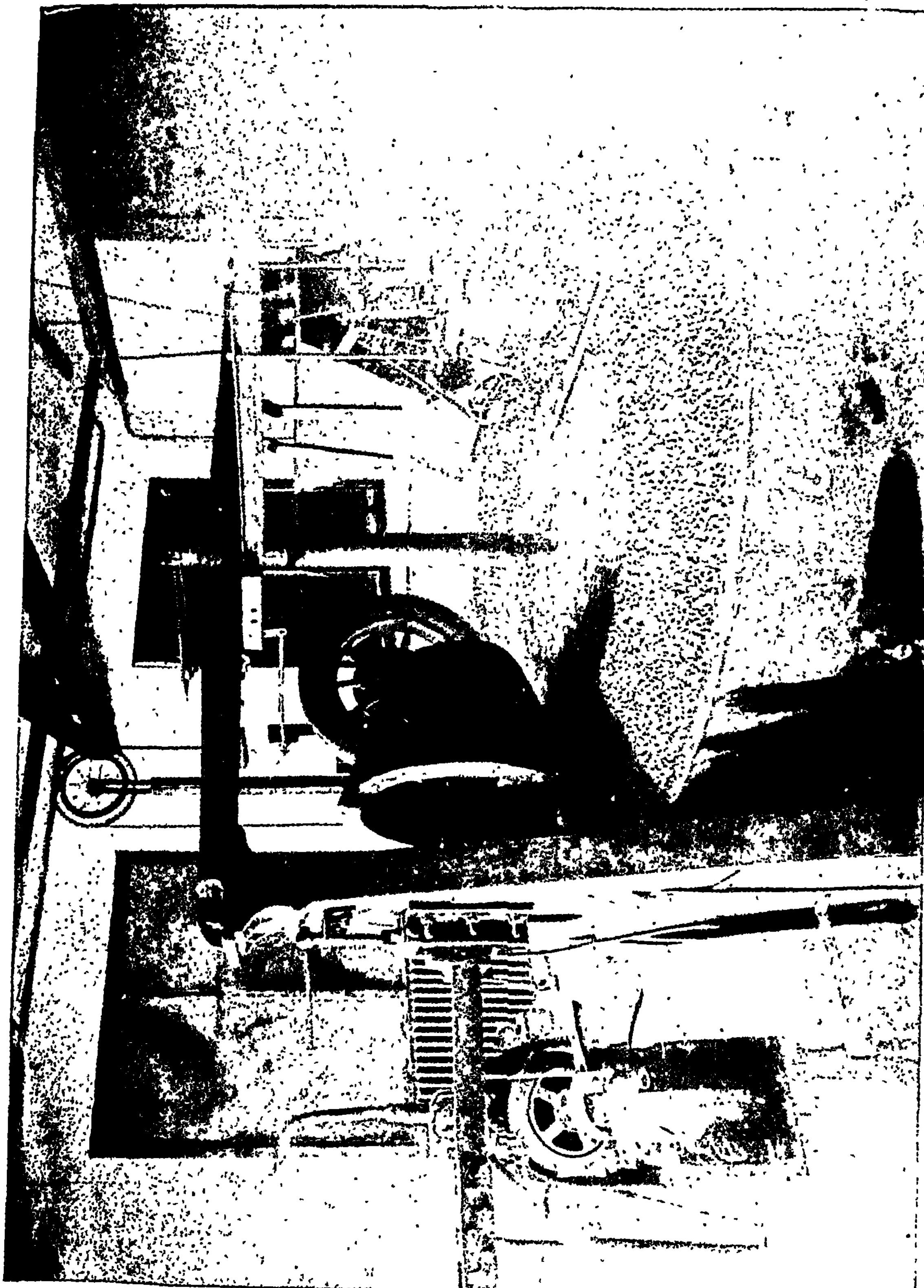

Fig. II. No. 1 Testing Machine at Harmondsworth.

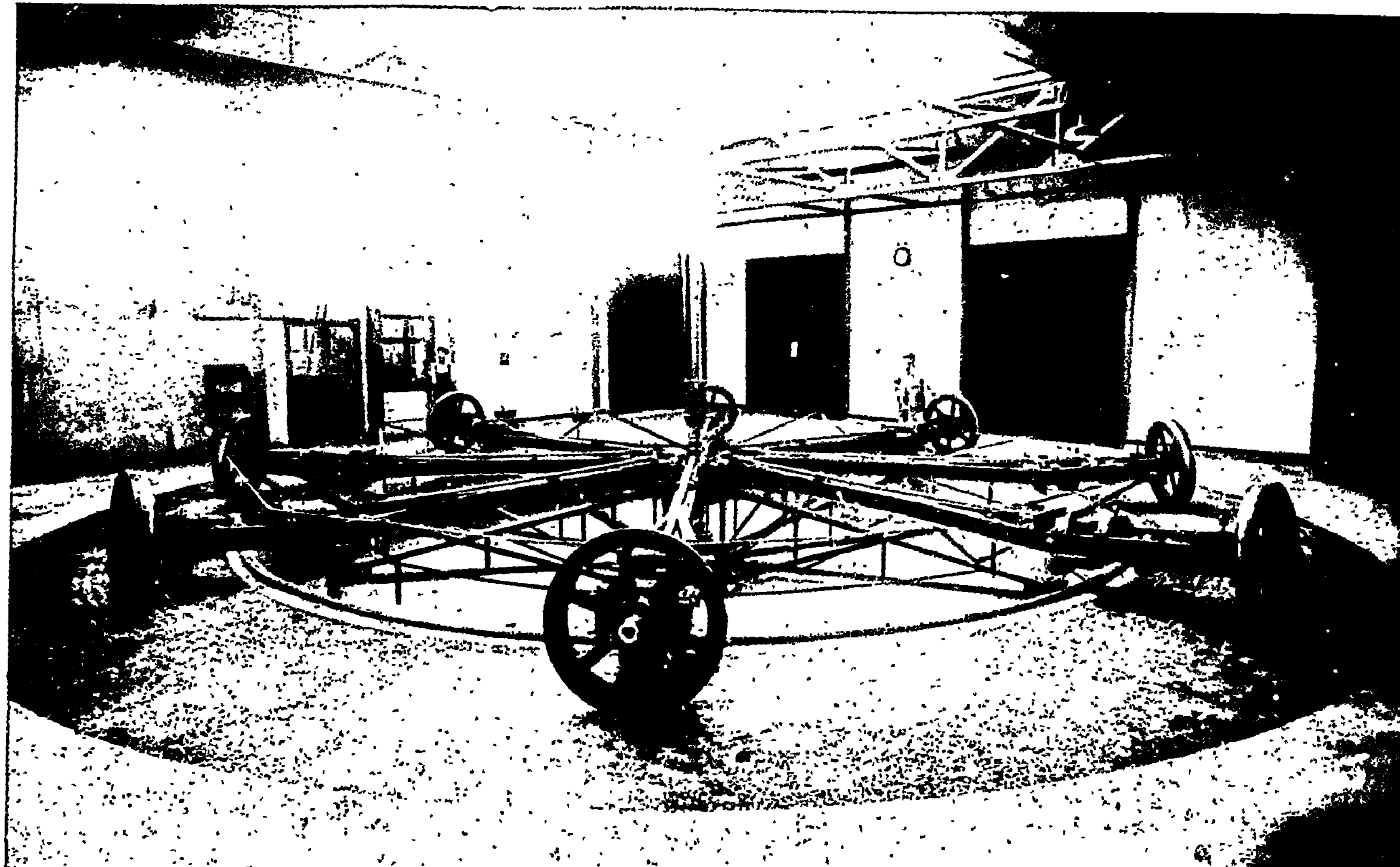

Fig. III. No. 2 Test Machine at Harmondsworth ready for action. Note that each Test Wheel has its own motor and that these wheels do not track.

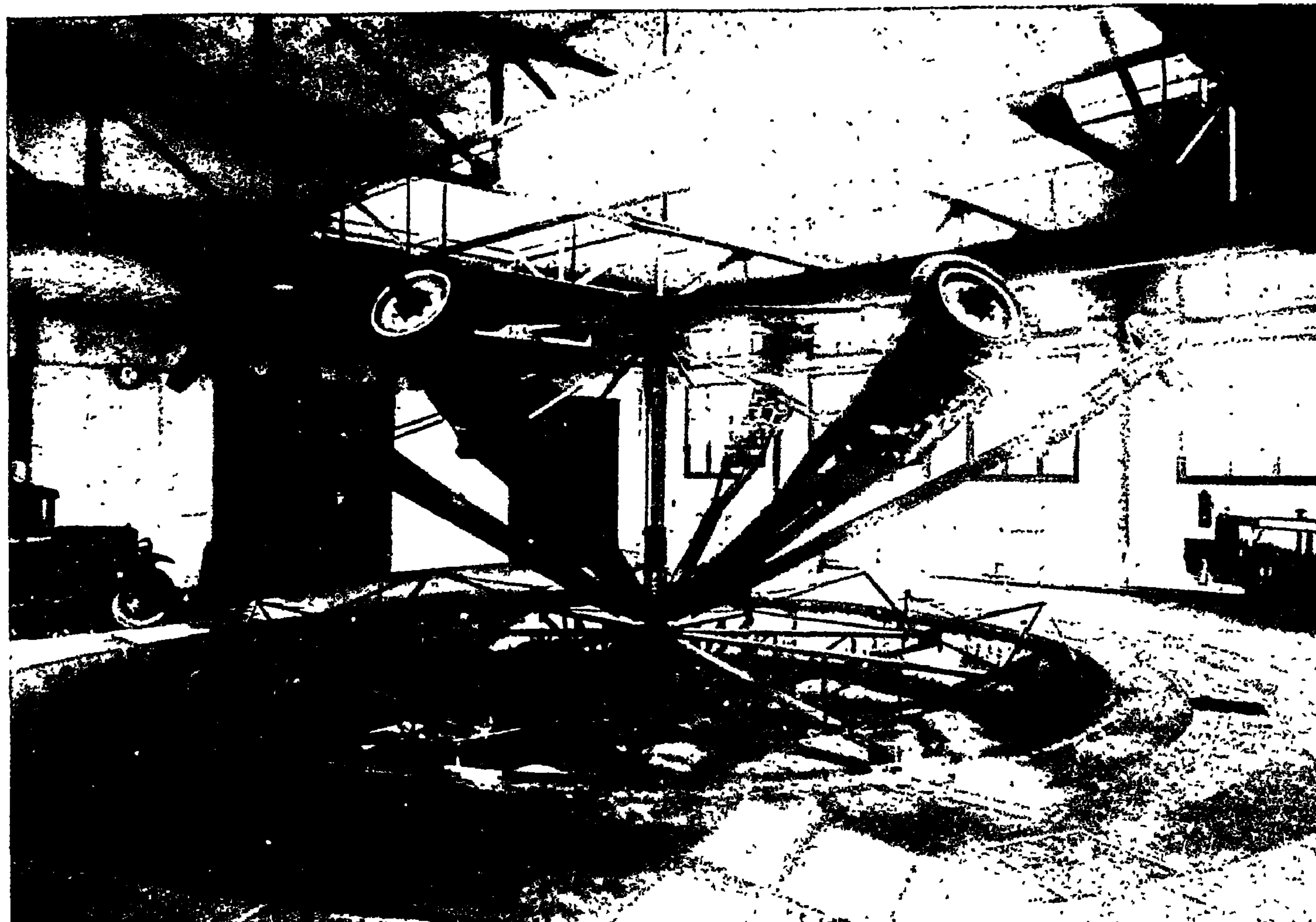

Fig. IV. No. 2 Test Machine at Harmondsworth with radial arms raised for laying of Test Surfaces.

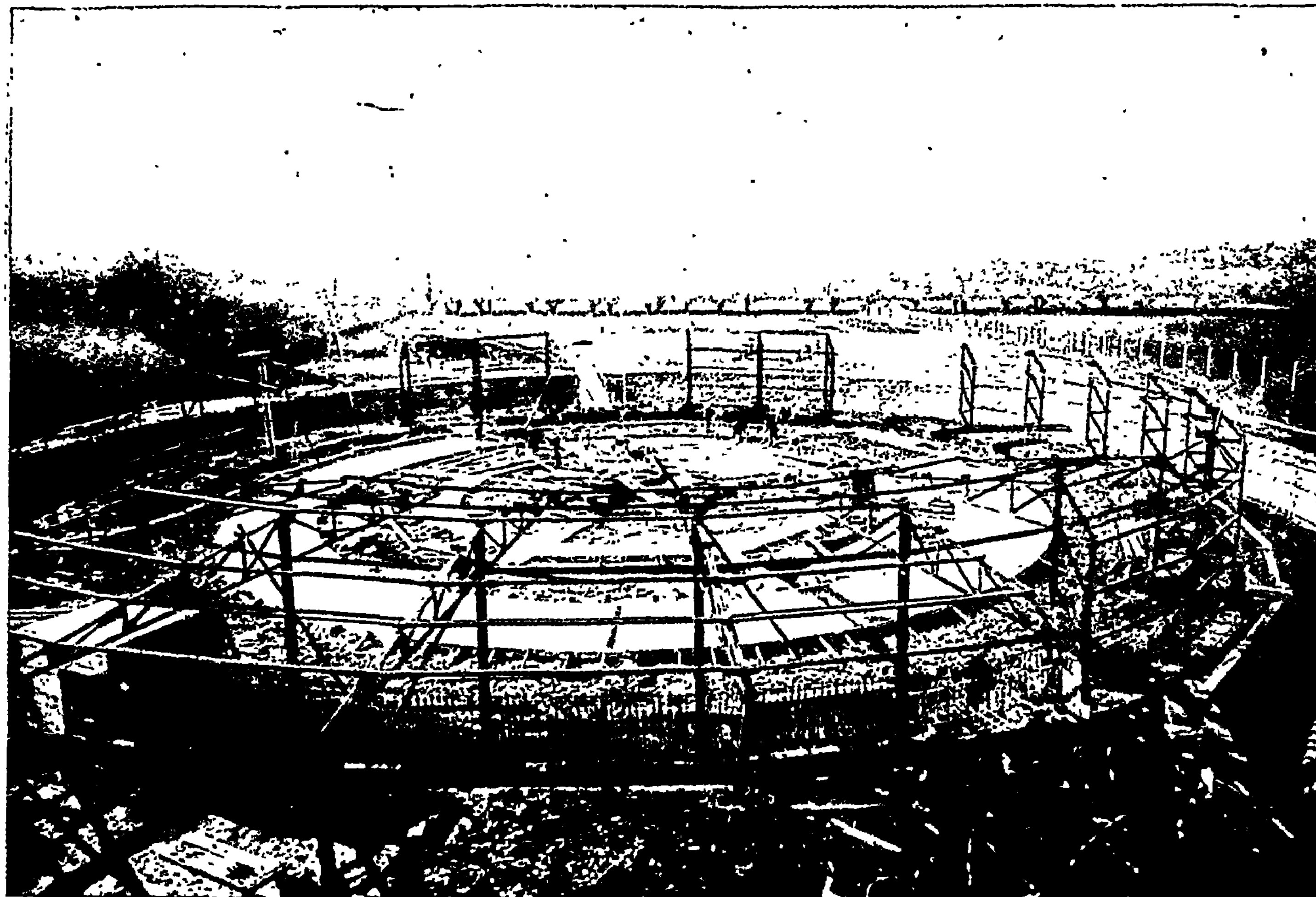

Fig. VI. No. 3 Test Machine at Harmondsworth underconstruction. Note Sandbag retaining wall to catch lorry in case of accidents.

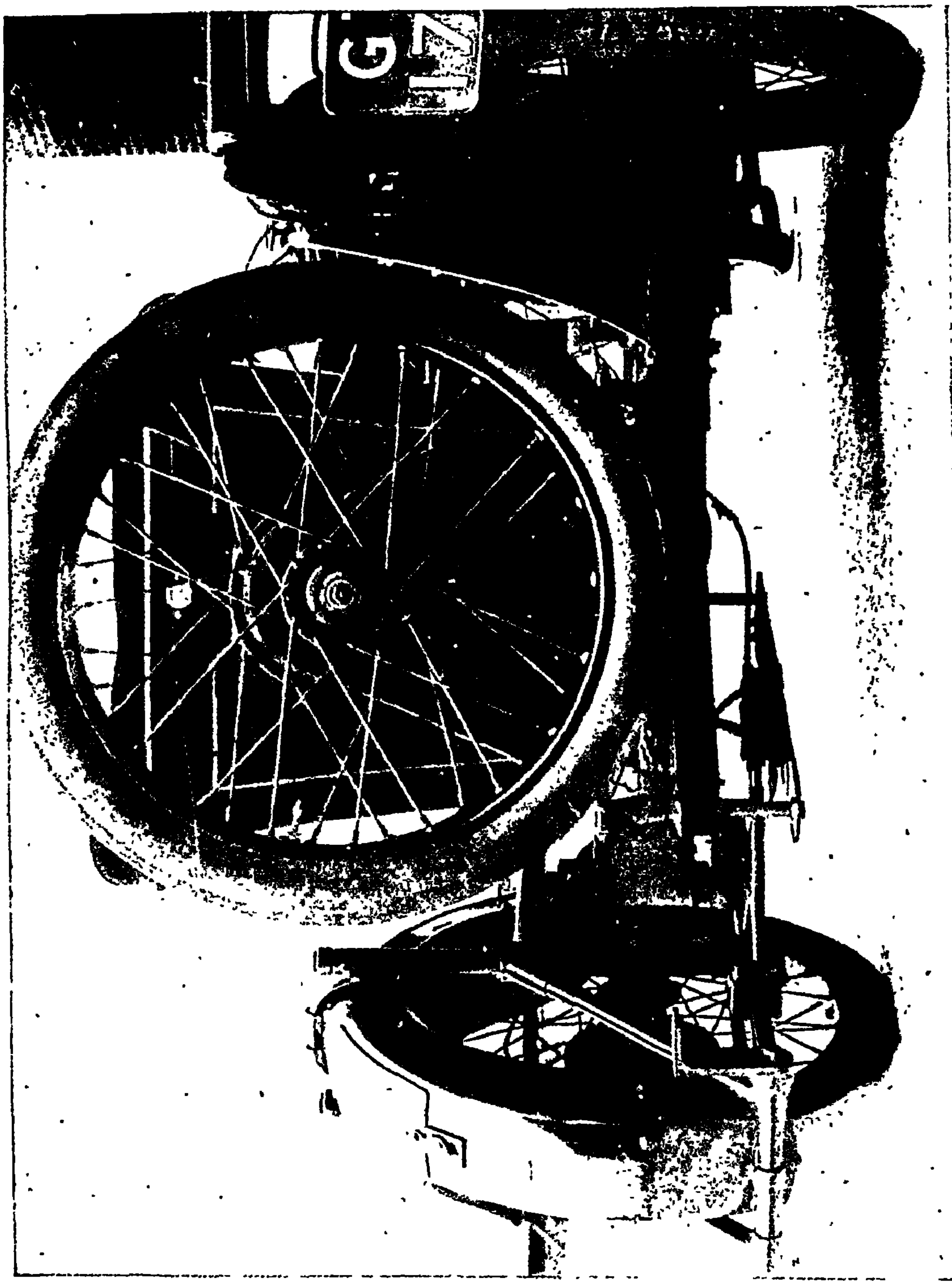

Fig. VII. The Skid Machine for measuring and recording.

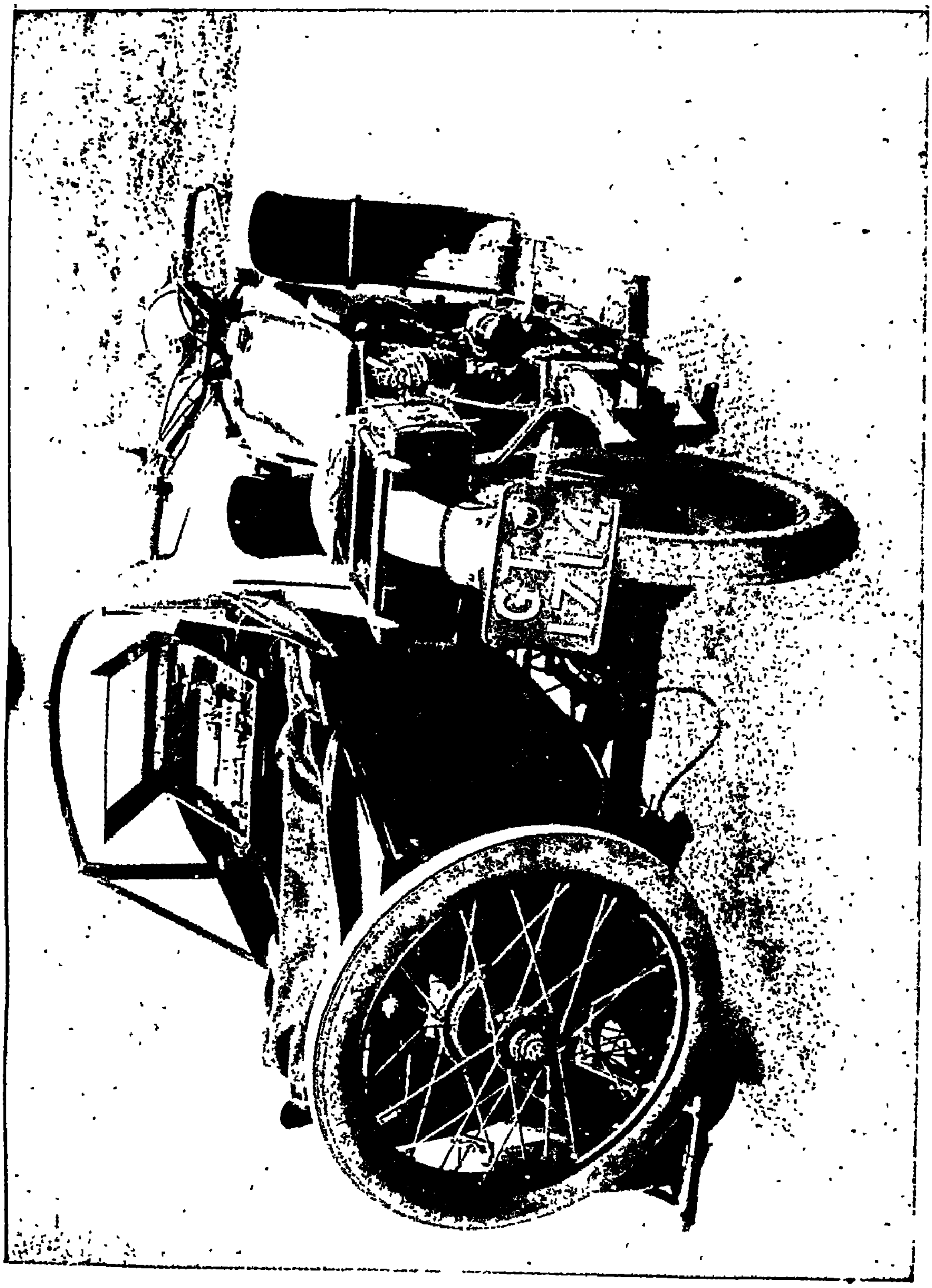

Fig. VIII. The Skid Machine showing the recording device.

DISCUSSION ON PAPERS (NOS. 21 & 22) IN GROUP 4.

Mr. C. D. N. Meares:—In introducing this Paper to you I would like to mention briefly some remarks made by Dewan Bahadur N. N. Ayyangar and others in regard to the ordinary water-bound macadam road and bullock cart traffic. It seems to me that the general opinion is that a water-bound road can successfully stand up to bullock cart traffic but deteriorates rapidly under the stress of motor car traffic. It also appears that the general opinion is that the reverse also holds good, namely, that the average bituminous pavement stands up to cars but breaks down under bullock carts. If we can construct a road which will stand up to bullock carts and then treat it in some way as to defeat the motor car we will get the ideal condition required. I refer you in this connexion to Sections 17, 18 and 19 of my Paper and leave you to draw your own conclusions. There is no question at all, as Mr. Mitchell remarked a few minutes ago, that the stone ultimately carries the traffic. If therefore, you treat a water bound surface in such a way that it is water-proof and dust-proof there is no reason at all why that road should not stand up to both kinds of traffic, namely, the bullock-cart and the motor car.

Chairman:—Papers 21 and 22 are now open for discussion.

Mr. T. R. Ramaswamy Ayyar:—The results of the experiments done on road surfaces as given in paper No. 21 are very interesting. If the author had also given an idea of the traffic carried on those roads it would help us to make a comparative study and will be useful.

Mr. G. Reidshaw:—I wish to refer to one or two little matters. In page 133, paragraph 5 of his Paper (No. 21), Mr. Mitchell states that unmetalled roads are regarded as hopeless. In Assam, however, it is not so and our experience there is quite different. Conditions concerning these roads in Assam are now far different from what they were four or five years ago. Roads which were then impassable for seven months in the year that is absolutely impassable for motor traffic, are now in such a condition that you can drive at 45 to 50 miles an hour for eleven-and-a-half months in the year. For the other fortnight there may be heavy rainfall causing floods as the annual rainfall in Assam varies from 50 inches to 16 yards per annum! (Laughter). This improvement is entirely due to mechanical methods of maintenance followed by gravelling. By mechanical methods, I mean the use of units such as the Caterpillar tractors, graders and planers. When the road is prepared and sectioned we give about 1½ inch to 2 inch thickness of gravel and the roads remain in excellent condition throughout the year. If more particulars of the plant used are required I will refer you to Mr. Fetters who will give you all the details. I can assure you that when Mr. Fetters says that a machine will do a particular work it will do it; he does not exaggerate (Hear, hear).

This improvement in communication has been brought about at considerable saving over the old hand-method of maintenance. We find that gravel, even when its cost is as high as Rs. 30 per 100 cubic feet represents a great saving. It has been stated that a light loam containing 40 per cent. of sand can effect an improvement on an earth road. That may be all right in the Punjab; but in Assam the proportion would not suit during our heavy rains. There is a reference in the Paper to trackways and the possible difficulty of bullock carts getting off the tracks and getting stuck on the earthen sides. Not only do they not get stuck on the earthen sides, but the ordinary earthen sides abutting the trackways are hardly indented in any place. This is because two bullock carts seldom leave the trackway at the same spot.

Mr. A. Lakshminarayana Rao:—It is stated that no amount of sanding can improve roads in black cotton soil. This is contrary to my experience. Annual mixing of sand 3 inches thick for three to four years has done much good to roads and we were able to lay metal on such roads without first laying soling. For example I may refer to the old Madras Road in Guntur where we spread sand on black cotton soil surface regularly for four years. When such an admixture is unsuccessful, the reason usually is largely the heavy quantity of sand applied in one year. If, year after year, 3 inches of sand are added on top of the soil, it will be so successful that you will find that the surface will keep smooth for a long time.

It is a matter for regret that the bullock cart is again and again referred to as destructive. Yesterday, Mr. Mitchell was telling us that so far as water-bound macadam is concerned the bullock cart is not the most destructive agent and I believe that it has been the general opinion. The bullock cart is said to be destructive for tar roads. But out of 3,00,000 miles of roads in India, not even 3,000 miles, or 1 per cent. are tarred roads. What then is the use of condemning the double bullock cart? On the average, it may be said that there is one double bullock cart for every 40 of population—I speak subject to correction. It may, therefore, be taken that there are 8 to 9 crores of double bullock carts as against 1,75,000 motors. What then is the use of condemning the carriers of what is probably the life-blood of the Indian Nation?

To equip all these carts with pneumatic tyres, will cost at least 1,200 to 1,350 crores of rupees at Rs. 150 per cart. Is it then a practical question to think of substitution of bullock cart or its iron tyre by anything? I appeal to Engineers to concentrate their attention on the best method of combating the problems as they are.

I beg of you not to take it that I am advocating the continuance of old methods alone to the exclusion of modern methods, which are decidedly improved methods, but let us evolve something suited to our country with its double bullock cart and its inevitable iron tyre.

In this connection, I make to you an humble suggestion, particularly to the administrative heads. The treatment of roads by improved methods is not merely a question of improving the roads of the country. By making them dustless, we are improving the health of the users of the road and preventing the spread of diseases like tuberculosis etc. Is it not, therefore, fair that a moiety of the cost of improvements is charged to the Public Health Budget of the Presidency? (Hear, hear) and I, therefore, bring this aspect to you, for making a move if the suggestion is acceptable to you.

Mr. B. N. Shenoy:—Comparison has been made as to the relative adequacy of sand and gravel for treating black cotton soil. I am afraid it is not the relative adequacy which we have to compare. Both sand and gravel are necessary for treating black cotton soil. The chief defect of black cotton soil is its inability to bear loads when it gets wet. So, a certain amount of rigidity has to be provided for it during wet weather.

The first thing is to put on black cotton soil as much of sand as necessary and work the sand into the wet soil and then to roll it. Then give a cushion coat of absolutely pure gravel without any admixture of clay to a thickness of between six to nine inches and form the road as a ridge.

By the adoption of this mixed treatment, namely treatment with sand and gravel, the road is brought up to a beautiful hard bed which will conveniently carry a load of 300 to 400 carts per day. In a recent trial which I made on a road with this treatment the result was absolutely satisfactory. The soft metal with which one would otherwise treat such black cotton soil surfaces costs about Rs. 12 per 100 cubic feet, whereas we can get the required quantities of gravel and sand from near-by places where it is easily had for about half that cost. In this manner I have secured a sub-grade which has stood up very well indeed under a traffic of about 300 carts and about 10 buses a day.

Mr. N. V. Modak*:—In paragraph 27 of Paper 21, Mr. Mitchell states that cement concrete roads have generally been successful in resisting bullock cart and mixed traffic. Unfortunately, our experience in Bombay is not so. In our residential areas, which carry light traffic, cement concrete roads have stood up fairly satisfactorily but where the loads exceed about 800 tons per yard width they have not been satisfactory at all. We have carried out the work of road construction to the specification of the Concrete Association of India. We cannot however say that our stones, used in the cement concrete mixtures, have been very good. It may be there were some defects in these stones. We intend getting the stones which we generally use tested and we are taking serious consideration of this point in our future programme of cement concrete roads. One of our cement concrete roads gave way within a year after the laying, necessitating our relaying it with asphalt pavement.

Another remark of Mr. Mitchell refers to asphalts and tars used by us. We are entirely in the hands of the manufacturers as regards the quality of the materials supplied to us. While one manufacturer claims that oil asphalt is best suited for road surfaces another manufacturer condemns it. We are therefore grouping in the dark in respect of the relative merits of the different materials we handle. We do not know which asphalt is better. The Technical Sub-Committee should do something in this matter and not let us continue grouping in the dark.

Mr. E. F. G. Gilmore:—I did not intend to say anything; but, it is perhaps desirable to say a few words about the proposed Test Track to which the paper circulated today and the report of the Technical Sub-Committee refer. In the Government Test House at Alipore, most of you, I feel certain, will be aware, we have been engaged for many years in routine testing of various road materials in common use—road materials such as road metals, cements, bitumen, tars, asphalt, etc. In connexion with this work considerable amount of testing plant and apparatus, and also experience about the characteristics of the various materials handled have been accumulated. I would like to refer you to the pamphlet recently issued by the Geological Survey of India, which Mr. Mitchell also mentioned just now. Therein has been collected together in a handy form the results of our tests for many years. The results are tabulated province by province according to the different materials received therefrom.

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*Note.—With the permission of the Chairman (Mr. S. G. Stubbs) the following remarks communicated by Mr. N. V. Modak by correspondence are reproduced in amplification of his remarks regarding cement concrete roads :—

"One of our older cement concrete roads constructed in the year 1924 gave way within a year after its construction. It was of course constructed in accordance with the best specification known at that time. It should however be noted that since that time there has been considerable improvement in the technique of cement concrete road construction and it is believed that with the advance of time the present technique would be improved so as to get over the defects at present noticed in the roads in order to enable them to withstand the demands of modern traffic."

With regard to the proposed Test Track, it is contemplated that it should be practically identical with that installed at Bandoeng (Dutch East Indies) details of which were published in the proceedings of the Inaugural Meeting of the Congress. Certain modifications have, however, to be made on account of the limited space available in the compound of the Government Test House at Alipore. It is proposed that instead of having two 50-feet radius ends we should have one with a radius of 40 feet and the other with a radius of 50 feet. In Mr. Meares' Paper No. 13 (in the Proceedings of the Inaugural Meeting of the Congress) the track was arranged to be symmetrical in order to make possible the alignment of four tracks. It is not possible to do that in our design where we have allowed for tracks with differing radii. All the details of the designs are however still in a preliminary stage. The designs and their details are now well in hand and in the near future I hope to be able to put up detailed proposals as regards the tracks and the staff that will be required. At the Government Test House we have considerable experience as regards the characteristics of certain materials in common use in road construction in India but we have no experience at present as regards actual road construction. It is a matter for discussion as to how best we should constitute a staff which will, for purposes of the Test Track, have to handle problems of road construction and not merely of the materials used therein.

Chairman:—Before closing this discussion I wish to make some brief observations. During the course of the discussion of Papers Nos. 21 and 22 the quality of hardness of the aggregate has been dwelt upon. The importance of this cannot be over emphasised. It has to be borne in mind that with heavy cart traffic with iron wheels a road will sooner or later fail through crushing whatever the specification, unless the aggregate is really hard. For surface painting with tar or bitumen not only is it necessary to have a hard aggregate but it must also be well graded so that all the particles are in close contact with one another in order to reduce the crushing of the aggregates to a minimum. Recent experiments in the Punjab indicate that by precoating the aggregate with tar or bitumen and subsequently coating it with dry sand the power of resistance to crushing of the aggregate is increased considerably. In paragraph 8 of his paper No. 21 Mr. Mitchell says: "The opinions of Messrs Stubbs and Breadon closely coincide but they contrast remarkably with that of Col. Wakely" Mr. Mitchell continues to speak of the best proportions for the materials of an earth road. I presume that Col. Wakely's experience is of soil containing sharp sand, in which case only a small quantity of clay is required to bind it together. We in the Punjab however, rely mainly on the clay. The function of the sand is merely to add stability.

I may also mention that in connection with the criticism on bullock carts it was stated by one speaker that about only one per cent. of the roads in India were tarred. In the Punjab, however, the Provincial roads are almost 100 per cent. tarred (cheers).

I have great pleasure in proposing a vote of thanks to Mr. Mitchell and to Mr. Meares for their valuable papers and to the speakers for the interesting discussion.

We will now adjourn for the Council Meeting.

After the Council Meeting the lunch interval was held.

Second day, Friday, January 10, 1936 (contd.).

BUSINESS SESSION.

CHAIRMAN :—*Rai Bahadur Chhuttan Lal.*

The Congress reassembled at the Sir Puttana Chetty Town Hall after the luncheon interval, at 2-15 P. M., for the Business session with Rai Bahadur Chhuttan Lal, the newly elected President in the Chair. The following Report of the Council to the Annual General Meeting was considered.

Report of the Council to the Annual General Meeting.

Introductory.—The provisional Committee set up at the time of last year's Congress in Delhi has during the year discharged the office of the Council as provided for in the proposed Rules and Regulations now presented to the Congress and reports to the Congress accordingly.

2. *Memorandum of Association, Rules and Regulations and By-Laws of the Indian Roads Congress.*—The draft attached* at appendix A is recommended for adoption by the Congress. Attention is directed to three departures for the proposals outlined last year. One is that no entrance fee should be levied from ordinary or associate members who join before the end of September 1936. The second is that it has been necessary, in order to provide for adequate representation to increase the number of members of the Council from Indian States to nine. The third is that the general body of the Congress is to elect four members of Council each year in order to secure the election of some particular individual or the representation of some particular group as the general body of members may desire. The Council will then, with the creation of two new Provinces, consist of—

Representatives of local Governments	12
Central Public Works Department	1
Government of India	1
Royal Engineers	1
States	9
Business	6
General	4
	34

This is a large body which will meet only once or twice a year, but can be referred to at other times by correspondence which is provided for in the constitution. Delegation of powers to sub-committees is also provided for.

* The original draft appended to the Report of the Council is not reproduced. The memorandum of Association, Rules and Regulations and Bylaws as approved at the 'Business Session' were thereafter vetted by the Solicitor to the Government of India and circulated to all members of the Council. The documents as finally approved by the Council are reproduced as appendix A to the report of the Council.

3. *Technical recommendations.*—The provisional committee last year appointed a technical sub-committee consisting of Mr. K. G. Mitchell, Mr. S. G. Stubbs, Major W. B. Whishaw, R. E., and Mr. G. G. C. Adami to report on certain matters. Mr. C. D. N. Meares was subsequently co-opted as a member of the sub-committee in the place of the late Mr. Adami. The Council have received and considered the report of this Sub-Committee which they have amended in certain respects and now present (at Appendix B) for adoption by the Congress. In particular the Council draw attention to the following recommendations:

(*i*) Standard units of weight, measure and cost to be generally adopted (Para. 5 of the Report Appendix B).

(*ii*) Standard method of recording particulars of experimental work (Para. 6 and Enclosure II of the Report).

(*iii*) Standard specification for sizes of broken stone (Para. 8 of the Report).

(*iv*) Standard nomenclature and definitions for bituminous material and types of construction (Para. 10 of the Report).

(*v*) Standard method of recording traffic statistics (Paras. 12 and 13 of the Report).

(*vi*) Proposals in connection with the installation of test tracks and a research station or stations (Paras. 15 and 17 of the Report).

4. *Standard Road Signs.*—The Council recommend for adoption by the Congress—

(*i*) the standard gauge for indicating to the public the depth of water over dips, causeways, etc. (Enclosure III of the Report) and consider that only one or two such gauges should be placed at each site so as to be clearly visible to any one before driving into the water; that they should be placed on the up stream side and be clearly distinguishable; and that no attempt should be made to paint the gauge on down stream side protective railings or posts.

(*ii*) Sign indicating "Narrow Bridge" (Enclosure IV of the Report).

5. *Earth road and soil research.*—The Council endorse the recommendation contained in para. 22 of the report that a scientific study of soils should be initiated by the appointment of a special officer to study the question on the lines recommended. They consider that the officer should be an Engineer with ripe experience of roads in India to be assisted later if necessary by a physicist and chemist; that the status and pay of the officer should be such that his opinion and recommendations would carry weight and should not be less than that of a Superintending Engineer in the Public Works Department. They further consider that it would be unreasonable to look for tangible results in less than five years and that the cost might therefore be some Rs. 1½ to 2 lakhs. In view of the immense milage of unmetalled roads and of the importance of the subject the Council consider that such expenditure would be justified even if the results were largely negative.

6. The Congress is invited to accept these various recommendations by formal Resolutions.

APPENDIX A.

MEMORANDUM OF ASSOCIATION AND RULES AND REGULATIONS AND BYE-LAWS.
In the matter of the Indian Societies Registration Act XXI of 1860.

AND

In the matter of the Indian Roads Congress.

MEMORANDUM* OF ASSOCIATION OF THE INDIAN ROADS. CONGRESS.

1. *Name.*—The name of the Society shall be "The Indian Roads Congress".

2. *Objects.*—The objects of the Society shall be—

(*a*) to promote the science and practice of road building and maintenance;

(*b*) to provide a channel for the expression of the collective opinion of its members on matters affecting roads;

(*c*) to promote the use of standard specifications and to propose specification;

(*d*) to advise regarding education, experiment and research connected with roads;

(*e*) to hold periodical meetings to discuss technical questions regarding roads;

(*f*) to accept subscriptions, donations, endowments and gifts in furtherance of the objects of the Society;

(*g*) to invest and deal with the funds of the Society or entrusted to the Society or permit same to be held by the Government of India or a Bank and to acquire and hold any movable or immovable property for the furtherance of the objects of the Society and to sell, lease, exchange or otherwise deal with same;

(*h*) to grant pay, prizes, honoraria or scholarships (including travelling scholarships) for meritorious work in furtherance of the objects of the Society;

(*i*) to publish or arrange for the publication of magazines or other writings;

(*j*) to do all such other lawful things as may be incidental or conducive to the attainment of the above objects.

3. *Income and property.*—The income and property of the Society whencesoever derived shall be applied solely towards the promotion of the objects of the Society as herein set forth and no portion thereof shall be paid or transferred or distributed directly or indirectly by way of dividend, bonus

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* The original draft appended to the Report of the Council is not reproduced. The Memorandum of Association, Rules and Regulations and Bye-laws as approved at the Business Session were thereafter vetted by the Solicitor to the Government of India and are reproduced as subsequently finally approved after circulation to all members of the Council of the Indian Roads Congress.

or interest or otherwise howsoever by way of profit to the members of the Society: Provided that this shall not prevent the payment in good faith of remuneration to any officer or servant of the Society or other persons in return for services rendered.

4. The Governing Body of the Society shall be the Council as constituted by the Rules and Regulations of the Society: Provided that until the first annual general meeting of the Society the Governing Body shall be:—

Provinces.

Name.	Address and occupation.
1. Mr. A. Vipan	Special Officer for Road Development, Local Self Government Department, Madras.
2. Mr. L. E. Greening	Deputy Secretary to the Government of Bombay, Public Works Department.
3. Mr. D. J. Blomfield	Chief Engineer, Bengal Public Works Department.
4. Mr. C. F. Hunter	Superintending Engineer, United Provinces, Public Works Department, Buildings and Roads Branch.
5. Mr. S. G. Stubbs, O.B.E.	Chief Engineer, Punjab, Public Works Department, Buildings and Roads Branch.
6. Mr. O. H. Teulon	Chief Engineer, Burma, Public Works Department, Buildings and Roads Branch.
7. Mr. N. G. Dunbar	Deputy Chief Engineer, Bihar and Orissa, Public Works Department, Buildings and Roads Branch.
8. Mr. A. H. Hyde, M.C.	Chief Engineer, Central Provinces, Public Works Department, Buildings and Roads Branch.
9. Mr. B. F. Taylor, V.D.	Superintending Engineer, Assam, Public Works Department.
10. Mr. G. A. M. Brown, O.B.E.	North-West Frontier Province, Public Works Department, Buildings and Roads Branch.
11. Mr. A. Brebner, C.I.E.	Chief Engineer, Central Public Works Department.

Government of India.

12. Mr. K. G. Mitchell, C.I.E.	Consulting Engineer to the Government of India (Roads).

Indian States.

13. Rai Bahadur A. P. Varma	Chief Engineer, Patiala.
14. Diwan Bahadur N. N. Ayyangar	Chief Engineer, Mysore.
15. Mr. P. L. Bowers, C.I.E., M.C.	Chief Engineer, Jaipur.
16. Rai Bahadur S. N. Bhaduri	Chief Engineer, Gwalior.
17. Mr. M. A. Zeman	Chief Engineer, Drainage Department, Hyderabad Deccan.

Business.

18. Mr. H. E. Ormerod	The Indian Roads and Transport Development Association, Bombay.
19. Col. G. E. Sopwith	Messrs. Turner Morrison and Company, Calcutta.
20. Mr. C. D. N. Meares	Messrs. The Standard Vacuum Oil Company, Calcutta.

Military Engineer, Services.

21. Major W. B. Whishaw, M.C., R.E.	Engineer-in-Chief's Branch, Army Headquarters, India.

We, the several members of the Governing Body whose names and addresses are subscribed are desirous of being formed into a Society in pursuance of this Memorandum of Association.

RULES AND REGULATIONS OF THE INDIAN ROADS CONGRESS

I. MEMBERSHIP.

1. The Society shall consist of—

(*a*) Such persons as accept the invitation of the Council to be a Patron or a Vice-Patron of the Society from time to time: Provided that there shall never be more than one Patron and 12 Vice-Patrons at any one time.

(*b*) Ordinary Members who shall be such qualified Engineers who are or have been connected with Roads, as may be elected as ordinary members of the Society by the Council.

The expression "qualified Engineer" shall for the purpose of this Rule be deemed to include—

(*i*) Chartered Civil Engineers of the Institution of Civil Engineers of England or the Institutions of Engineers (India).

(*ii*) Regular Officers or Ex-Regular Officers of the Corps of Royal Engineers.

(*iii*) Persons holding any academic degree or diploma accepted by the Institution of Engineers, India, as qualification for corporate membership; and

(*iv*) any person who shall, in the opinion of the Council, by reason of academic qualification or long practice in engineering or otherwise be sufficiently qualified in engineering to bring him within the said expression.

The expression "connected with Roads" shall for the purposes of this Rule be deemed to include being or having been—

(*i*) incharge of roads, or

(*ii*) connected with the construction and maintenance of roads, or

(*iii*) otherwise engaged (whether in public employ or in business or otherwise) in connection with roads or material used in connection with roads or the use of roads or in writing about the same or otherwise connected with roads to an extent in the opinion of the Council sufficient to bring a person within the said expression.

(*c*) Associate Members who shall be persons who, while not eligible to be ordinary members, are or have been in the opinion of the Council, engaged in the administration of roads or road transport or so engaged in business connected with the construction and maintenance of roads or with the manufacture or sale of material used in connection with the making or repairing of roads or of road transport vehicles, or the operation thereof as to render them sufficiently qualified to be eligible for Associate Membership of the Society.

(*d*) Honorary Members who shall be such persons as the Council shall, from time to time, elect as Honorary Members on account of being in their opinion sufficiently distinguished men or interested in roads as to make it desirable that they should be given Honorary Membership of the Society. They shall at no time exceed fifty in number.

2. *Entrance Fee.*—An entrance fee shall be payable by members on election on the following scale:—

	Rs.
Patrons, Vice-Patrons and Honorary Members	..
Ordinary Members	10
Associate Members	50

(i) Provided that no entrance fee shall be payable by any member who pays his first subscription on or before the thirtieth day of September 1936.

(ii) Provided further that no entrance fee shall be payable by any member who shows to the satisfaction of the Council that his total emoluments at the date of his election are not more than Rs. 400 per mensem.

3. *Subscription.*—A yearly subscription shall be payable by members on the following scale:—

	Rs.
Patrons, Vice-Patrons and Honorary Members	..
Ordinary Members	10
Associate Members	50

A year shall for the purpose of this Rule, be from the first day of October until the last day of September following. Subscriptions shall be due on election and on the first day of October of every year following that date that a person continues to be a member of the society. Provided that if a person is elected a member of the Society after the 31st March in any year he shall only pay half subscription for that year.

4. *Cessation of Membership.*—Any member who has to pay subscriptions and has not paid his subscription for two years shall automatically cease to be a Member and the Council shall have power to cancel the Membership of any member of the Society who shall be deemed to have been guilty of any conduct prejudicial to the Society or rendering him unfit to remain a member thereof.

Provided that at least 2/3rds of the Members of the Council present in person or by proxy shall be in favour of such action and Provided Further that before any decision is taken the Member in question shall be afforded an opportunity to state his case in person or writing. A member may also resign from his membership of the Society by notice in writing to the Secretary to that effect provided he is not in arrears with his subscription and that no such resignation shall be valid until the member resigning receives an acceptance of his resignation in writing from the Secretary.

II. GOVERNING BODY.

1. The Society shall be controlled by and the management of its affairs be entrusted to a Council constituted as follows:—

(*a*) A representative of each Presidency or Governor's Province to be nominated by the local Government concerned from Ordinary Members of the Society.

(*b*) A representative of the Military Engineer Services to be nominated by the Engineer-in-Chief, Army Headquarters, India from the Ordinary or Associate Members of the Society.

(*c*) A representative of the Central Public Works Department of the Government of India to be nominated by the Chief Engineer of that Department from the Ordinary Members of the Society.

(*d*) The Consulting Engineer to the Government of India (Roads) for the time being.

(*e*) Nine ordinary Members of the Society residing in or being subjects of an Indian State to be elected annually at the time of the annual general meeting by a Board consisting of one ordinary Member from each of the States or group of States specified in Schedule I present at the General meeting and nominated by such State or group of States as the case may be and Provided that in the event of any dispute regarding the member entitled to represent any State or group of States on the said Board the decision of the President of Society shall be final and Provided further that in the event of the votes of the said Board being equal the President of the Society shall have a second or casting vote.

(*f*) Six ordinary or associate Members of the Society (not being public servants) to be elected annually at the time of the annual general meeting by a Board consisting of the ordinary and associate members (not being public servants) present at the meeting. Provided that in the event of any dispute as to the composition of the Board the dispute shall be referred to the President of the Society for decision and his decision shall be final and Provided further that in the event of the votes being equal the President of the Society shall have a casting vote.

(*g*) Four ordinary or associate Members of the Society to be elected by the annual general meeting.

2. The Council shall at its first meeting after each Annual General Meetings elect the President and not more than three Vice-Presidents of the Society from among its own Members.

3. The Council shall appoint a Secretary and Treasurer on such terms as they deem fit.

4. The Council shall hold office from the conclusion of one annual meeting until the conclusion of the next annual meeting.

5. The Council shall have power:—

(*a*) to fill any vacancies on the Council that may occur as regards members elected under 1 (*c*) (*f*) (*g*) above between two Annual General Meetings, and

(*b*) to add to its number by co-opting not more than ten members of the Society such co-opted members shall however have no voting power.

6. Any member of the Council as aforesaid may nominate by written notice to the Secretary a member of the Society to represent and vote for him as a member of the Council.

7. The President or in his absence a Vice-President to be nominated by the President shall preside at all meetings of the Council if present, otherwise the meeting shall elect a Chairman. The Chairman shall have a casting vote.

8. The Council shall meet at least once a year at such times as the President may direct and one of such meetings shall be at the time of the General Meeting of the Society and on the requisition of at least six members the President shall call a meeting of the Council Provided that instead of actually meeting the President may direct that the Secretary refer the matter specified in the requisition for decision by post as hereinafter provided. At meetings of the Council five shall form a quorum.

9. The Secretary shall on the orders of the President refer any matter for the decision of the Council by sending to each Member of the Council a Memorandum setting forth the question or questions to be decided and specifying a date not less than thirty days from the date of posting of the Memorandum by which the votes of Members of the Council shall reach him. Upon receipt of not less than ten votes by the date specified, the Secretary shall record the decision of the Council as decided by the majority of the votes received by the said date and communicate such decision to the members of the Council. If less than ten votes are received by the said date it shall be presumed that no decision has made. In the event of the votes received by the Secretary as aforesaid being equal the President shall have a casting vote.

10. The Council may appoint from among its members a sub-committee of not less than three to discharge such of the functions of the Council as the Council may specify. The President and Secretary of the Society shall be *ex-officio* members of such sub-committee. The sub-Committee shall have power to co-opt not more than 3 members with power to vote. Three shall form a quorum. The President if present shall preside. If not present the sub-committee shall elect its own Chairman. The Chairman shall have a second or casting vote.

11. The Council may delegate the management of such affairs connected with the Society within any Governor's Province in British India or any Indian State as the Council shall direct to any member of the Society resident in any such Province or State and the said member of the Society may, (with the prior consent of the Council) set up an Advisory Committee of Members of the Society to assist him in such management and may appoint any person to act as Secretary to such a Committee. Such Advisory Committees shall include all Members of the Council resident in the Province or State concerned and shall normally include at least one member not being a public servant. All action taken under this Rule by the member aforesaid shall however be reported to the Council for confirmation.

12. The Council may appoint a Committee or Committees (with power to co-opt) to report on any matter and may sanction expenditure in connection therewith.

18. If at any time the President for the time being is absent from India he shall nominate a Vice-President to act for him. In the event of the President failing to nominate one of the Vice-Presidents as aforesaid then the Vice-Presidents shall elect one of themselves to perform the office of President.

III. Meetings of the Society.

1. There shall be a General Meeting of the Society once a year at such time and place as the Council shall decide for the purpose of disposing of the following business:—

   (a) to receive the report of the Council and the audited accounts for the previous year ending 30th September.

   (b) To elect four members of the Society to serve on the Council until the next General Meeting as aforesaid.

   (c) To appoint Auditors; and

   (d) to transact such other business as the President shall allow.

At Annual General Meetings the Council may arrange for Papers to be read on subjects of professional and technical interest and for discussion thereon and for works to be visited.

2. The President shall preside at all General Meetings of the Society or shall nominate a Vice-President or some other member of Council to preside in his place. In the absence of the President and of the Chairman nominated by the President at any meeting the members present shall elect a Chairman. The Chairman shall have a casting vote.

3. Twenty members present in person or by proxy shall form a quorum.

IV. Bye-Laws.

The Council shall have power to make, add to, abridge and amend such Bye-laws as may appear to the Council to be necessary for the conduct of the business of the Society, and as shall be consistent with the Memorandum and Rules and Regulations of the Society.

V. Alteration of Rules.

These Rules and Regulation shall not be altered, extended or abridged without the approval of at least 2/3rds of those present in person or by proxy at a meeting of the Council and at least 30 days' notice shall have been given of such meeting and of any proposal to alter, extend or abridge these Rules and Regulations.

Schedule I.

[Referred to in Section II 1 (c)].

1. States in the Central India States Agency.
2. States in the Rajputana States Agency.
3. States in the Western India States Agency.
4. States in the Gujarat States Agency and Baroda State.
5. States in the Eastern States Agency.

6. States in the Madras States Agency.
7. States in the Deccan States Agency and Kolhapur State.
8. States in the Punjab States Agency.
9. Hyderabad (Nizams Dominions).
10. Mysore State.
11. Gwalior State.

We being 3 members of the Governing Body, (The Council) of the Indian Roads Congress certify that above is a true copy of the Rules and Regulations of the Society.

1.................................

2.................................

3.................................

Bye-Laws.

1. Application for admission as an ordinary or associate member shall be made on the form annexed hereto addressed to the Secretary, Indian Roads Congress, Care of the Government of India, Department of Industries and Labour, Roads Branch.

2. The Council shall take such steps as may in its opinion be necessary to ascertain the suitability of the applicant.

3. No member whose subscription is more than thirty days in arrear shall be entitled to attend any meeting or to receive any publications of the Society.

4. At each General Meeting the Retiring President shall deliver an address dealing with matters of interest to the Society.

5. *Conduct of Meetings.*—The Chairman of any meeting shall have power to preserve order and to require any member who has spoken for more than ten minutes at any time or who has already, in the opinion of the Chairman, had sufficient opportunity to state his views, to resume his seat.

6. *Voting at Meetings.*—Votes at any meeting may be taken by a show of hands or by ballot in the discretion of the Chairman.

7. *Record of Proceedings.*—(*a*) The proceedings of all meetings shall be recorded under the orders of the Chairman. Copies of the record of the remarks made by any member at a General Meeting shall be sent to him for correction as soon as reasonably possible after the session at which the remarks were made. If these are returned duly confirmed or corrected within 30 days of despatch they will be incorporated in the published proceedings. If they are not returned within 30 days the editor of the proceedings shall, under the general instructions of the Chairman, have power to make such additions and corrections to the recorded remarks of any member as may be necessary in his judgment to secure an accurate record. Provided that the editor shall have power under the general control of the Council to reject additions or corrections which in his judgment do not represent what the member said and publish what he considers was said.

(*b*) Any member whether present during the discussion or not may send to the editor within 30 days of the discussion any comments on the subject matter of any paper or on the subject of any remarks in the course of any discussion and such comments may, in the discretion of the editor, be included in the record of the proceedings under a separate head entitled "Correspondence".

(8) *Publications.*—(1) In addition to the proceedings of General Meetings the Council shall have power—

(*a*) to issue any publications likely in the opinion of the Council to promote the objects of the Society;

(*b*) to accept advertisements on payment for insertion in any publication of the Society and to issue advertisements in any publication;

(*c*) to make payment for articles published;

(*d*) to fix the price of any publication; and

(*e*) to determine whether any publication shall be issued to members and associates free of cost or at a reduced cost.

(2) The proceedings of the annual meeting shall be issued to all members free of cost.

9. *Copyright.*—All papers accepted for discussion at meetings and all matters included in the proceedings and publications of the Society shall be the property of the Society and no member shall publish or otherwise make use for personal gain of any material included in the proceedings or publications save with the consent of the Council given under the hand of the Secretary.

INDIAN ROADS CONGRESS.

Form of Application for Membership.

I...of (address)
....
....
desire to become a Member (ordinary)/associate, of the Indian Roads Congress and agree that if admitted I will be subject to the Memorandum, Rules, and Regulations and the Bye-laws of the Society for the time being in force. I hereby declare that my academic qualifications are:—
....
....
....
My age is..................and I am now employed as...............................
....

Signature.

Dated...................................193 .

From our personal knowledge of the applicant we support his application.

....

....

APPENDIX B.

Report of the Technical Sub-Committee of the Indian Roads Congress.

[As adopted by the Council.]

A Sub-Committee consisting of

Mr. K. G. Mitchell, C.I.E., M.Inst.C.E.

Mr. S. G. Stubbs, O.B.E.

Major W. B. Whishaw, M.C., R.E., and

Mr. G. G. C. Adami.

was appointed by the Provisional Committee of the Congress on December the 13th 1934, to consider and report on a number of Technical questions. The sub-committee held a preliminary meeting the same day and two subsequent meetings in January and August 1935. Mr. C. D. N. Meares was co-opted a Member of the sub-committee in place of the late Mr. Adami but being absent from India between February and September was unable to attend any meeting. He contributed however by correspondence to the work of the Committee and collected valuable information on research and Research-Station equipment while abroad. Mr. R. L. Sondhi acted as Secretary to the sub-committee.

2. The sub-committee now submits its first report on the following subjects:—

I. Standard units of weight, measure and cost to be used in road specifications, estimates and reports.

II. Standard method and form for recording particulars of experiments carried out on roads.

III. Standard specifications for sizes of broken stone.

IV. Standard nomenclature for bituminous materials and types of construction.

V. Standard method of recording traffic statistics.

VI. Proposals for the installation of a test track, or tracks; for the adoption of standard tests and for the equipment of a research station or stations.

VII. Standard Road Signs.

VIII. Standard clearance for bridges over roads.

IX. Earth road and soil research.

X. Standard bridge loading.

XI. Library.

3. Before dealing with these questions the sub-committee desire to emphasise the importance of members of the Congress, and particularly of Chief Engineers, doing everything in their power to introduce and insist on the use of such standard units, forms, nomenclature, etc., proposed in this report as may be endorsed by the Congress as a whole. This report will first be presented to the provisional General Committee and by that body to the Congress with certain definite recommendations, but no proposals regarding standardisation can be of value unless all members of the congress are prepared, as far as they possibly can, to

accept and apply the considered recommendations of the majority. A change of units may be necessary in certain provinces, and may be troublesome. For instance people accustomed to describing surface painting in terms of gallons and square yards may find difficulty in adjusting their minds per 100 square feet, but once the adjustment is made and engineers throughout India think in the same terms the advantage will be obvious. A table of a few conversion figures is attached (Enclosure I to this Report).

I. Standard units of weight, measure and cost.

4. Difficulty in comparing specifications and costs is caused by varying practice. At present, surface treatments and grouts may be referred to in fractions of a gallon per square yard, square yards per gallon and gallons or pounds per hundred square feet and premixes may be specified as containing so many gallons of binder per 100 cubic feet. But asphalt and tar are invariably bought by weight. Road measurements and estimates of quantities are invariably in terms of feet, not yards, and it appears to be unnecessary as well as a nuisance to introduce any other units.

5. The sub-committee therefore recommends:—

(1) That surface treatments and grouts be specified and invariably described in terms of pounds per hundred square feet.

(2) That the asphaltic or tar binder in a premix be specified in terms of pounds and decimals per cubic foot of aggregate.

(3) That the cost of any road surfacing, grouting, premix or cement concrete surface should be stated in rupees and annas per hundred square feet.

II. Standard method and form for recording particulars of experiments carried out on roads.

6. It sometimes happens that when the time comes, which may be after several years, to deduce results from some experimental work or to compare it with some other, the value of the work is vitiated by lack of complete information about the specifications and particulars regarding construction. If it is left to someone to remember and put on record at the time of construction what information is likely to be required, some important particulars are almost certain to be forgotten, and the committee recommend the general adoption of the form at Enclosure II for all work—whether sanctioned as an experiment or not—regarding which information is likely to be required several years later.

III. Standard specifications of sizes of broken stone.

7. The British standard specifications in this matter are complicated by "tolerances" and there is the great difference between Indian and other broken stone that the former is still mainly hand broken. It is not therefore suitable for India to have specifications which presuppose mechanically crushed and graded stone of uniform sizes within certain "tolerances". In India also, although old specifications continue to mention a ring as the gauge, in actual practice stone is graded through square *mesh* sieves.

8. The committee recommend therefore that the following sizes only should be standardised and specified and that they should be defined as wholly passing one screen and wholly retained on another—which is in fact the way the stone is actually produced in practice.

Standard size.	Passing square mesh of	Retained on square mesh of
2½ inch	3 inch	2 inch.
2 inch	2½ inch	1½ inch.
1½ inch	2 inch	1 inch.
1 inch	1½ inch	¾ inch.
¾ inch	1 inch	½ inch.
½ inch	¾ inch	⅜ inch.
¼ inch	⅜ inch	$\frac{1}{16}$ inch.
Sand	$\frac{1}{16}$ inch	200 meshes to the inch.

IV. Standard nomenclature for bituminous materials and types of construction.

9. Definitions of the meanings of words such as bitumen and asphalt have been standardised in various countries, but many of these definitions appear to sacrifice practical commonsense to scientific purity. Most engineers are clear in their minds about the differences between, say, a residual bitumen and road tar, but the British Standard scientific definition of bitumen would include tar. For this reason British practice refers to bitumen other than tar as "asphaltic-bitumen" which in turn may cause confusion by suggesting to those not in touch with British practice that "asphaltic-bitumen" means only the bitumen found in natural asphalts. A similar complexity or lack of precision occurs in British nomenclature of asphaltic surfaces.

10. In India there are as yet no such well established definitions or names as to preclude us from making a fresh start, and the definitions recommended below are put forward as being based on commonsense and as sufficing—and the fewer the terms the better—for the needs of modern Indian practice.

A.—Materials.

(1) *Bitumen.*—A mixture of hydrocarbons completely soluble in carbon di-sulphide which is *characteristically* solid or semi-solid, black, and *sticky*, and which melts or softens on the application of heat.

(2) *Asphalt.*—A mixture of bitumen and mineral matter which may occur in natural deposits, or be produced by artificial means.

Note.—Scientifically, tar and tar-mineral mixtures would fall within the above definitions of bitumen and asphalt but are expressly excluded.

(3) *Road Tar.*—A bituminous product, viscous or liquid, resulting initially from the destructive distillation of coal and so refined as to be suitable for road work.

(4) *Cut-back.*—A solution of bitumen in a volatile or partly volatile solvent.

(5) *Road Emulsion.*—A liquid in which a substantial amount of bitumen or tar is suspended in water in a finely divided and stable state.

(6) *Filler.*—Mineral matter not less than 75 per cent. by weight of which passes a sieve of 200 meshes per lineal inch.

B.—Methods of construction.

(1) *Surface dressing.*—Spraying or painting a road surface with some binding material in a liquid state including the subsequent application of sand or fine stone.

(2) *Grouting.*—Pouring a binding material in a liquid state on to a partially consolidated surface of road metal so that the binder penetrates the interstice the consolidation being then completed with the addition of sand or fine stone.

NOTE.—It does not appear to be necessary to define "Seal", "Seal coat" or "Premixed seal".

(3) *Premix.*—The process of mixing mineral aggregates with bitumen or tar off the road and then placing and consolidating the mixture on the road.

(4) *Sheet asphalt.*—A premix of bitumen (with or without filler), and sand.

(NOTE.—Sheet asphalt may contain not more than 30 per cent. of fine stone.)

(5) *Asphaltic concrete.*—A premix of bitumen (with or without filler), sand, and not less than 30 per cent. by weight, of mineral aggregate of a size larger than sand.

(NOTE.—Sand is defined in paragraph 8 above as material passing a ten mesh sieve).

(6) *Asphaltic macadam.*—A mixture of bitumen (with or without filler), and a mineral aggregate of a size larger than sand. It can be made by the grouting or premix methods.

(7) *Tar concrete.*—As asphaltic concrete substituting "Tar" for "bitumen".

(8) *Tar macadam.*—As asphaltic macadam substituting "Tar" for "bitumen".

V. STANDARD METHOD OF RECORDING TRAFFIC STATISTICS.

11. The Sub-Committee feel that there has, in the past, been a tendency to elaborate traffic statistics unnecessarily. They believe that only two classes of traffic—motor vehicles and bullock carts—are of real importance in wearing out roads, that there is little to be learned from counting tongas and ekkas and nothing from counting pedestrians, cycles, cattle, etc., etc. They also consider that for ordinary rural road conditions where the metalled carriage way varies in width from say eight to sixteen or even twenty feet and berms may be of varying width and condition, information as to total numbers and weight of vehicles is of more significance than the same information reduced to a figure per yard width of hard surface.

12. It is therefore recommended that unless special refinements are wanted and particularly specified such as counts of other vehicles and pedestrians for the proper design of road widths and footpaths the following procedure be adopted. Traffic counts will be made and recorded in total numbers of vehicles under (*a*) motor transport [sub-divided into (1) buses and lorries and (2) cars] and (*b*) bullock carts sub-divided into those with iron or wooden tyres and, if necessary, into two wheeled and four wheeled carts. Average unit weights for each, *i.e.*, the average of all vehicles loaded and unloaded, having been determined the total tonnage will also be stated. The width of the metalled carriage way will be recorded but up to a width of 20 feet the weight per yard or foot width should not be worked out. For widths of metalled carriage way exceeding 20 feet where there is segregation of different classes of vehicles the widths of the separate traffic lanes may if considered necessary be determined in each case and separate statistics compiled for the different lanes.

13. In the case of earth roads of width greater than 20 feet, the statistics should be recorded per assumed traffic lane of ten feet in width, the width of the road to be taken to the nearest 10 feet.

VI. PROPOSALS FOR THE INSTALLATION OF A TEST TRACK OR TRACKS FOR THE ADOPTION OF STANDARD TESTS AND FOR THE EQUIPMENT OF A RESEARCH STATION OR STATIONS.

14. The first meeting of the Congress resulted *inter alia* in the unanimous adoption of a Resolution to the following effect, *vide* page 212 of the Proceedings:

> "This Congress recommends to the Government of India that a Central Road Research Station including a test track should be set up in Delhi and be financed from the Central Reserve in the Road Account."

But at the same time it was clear that the Congress as a body did not wish to hamper the discretion of the Technical Sub-Committee in this matter. The Sub-Committee took up this question at an early date and after an unfortunate delay owing to the death of Mr. Adami, who had undertaken to examine the equipment at the Government Test House at Alipore from this point of view, the question was proceeded with as rapidly as possible. The Committee now advise that it would be preferable to instal the first test track at Calcutta attached to the Government Test House at Alipore and not at Delhi and that at the same time the possibility of installing a second track in Northern India, say at Lahore or Roorkee, should be considered. The reasons which have led to abandoning Delhi are as follows: Delhi is visited only by persons who might be interested during five months in the year. Owing to the move of the Government of India to Simla, a test track at Delhi would be under the personal supervision of the Consulting Engineer to the Government of India (Roads) and his Assistant only for half the year. As part of the auxiliary equipment it would have been necessary to set up in Delhi a laboratory to control, against specifications, the materials being used on the test track, and that laboratory would have to be equipped with much apparatus already in existence at Alipore. Finally it appeared that there might be difficulty in arranging for the scientific establishment

of the new Agricultural research station to take over the entire control of the road research station. The Test House at Alipore is, on the other hand, already equipped with a great deal of the necessary control apparatus. It has a branch which is dealing with the testing of road materials. There is room in the compound to instal a suitable track and the Super intendent of the Test House is willing and anxious to co-operate in developing a complete road research station. Moreover in and around Delhi and in Northern India possibly more information has been obtained from direct trials on roads of the wearing qualities of different specifications under prevailing climatic conditions than anywhere else in India save in the special circumstances of the big cities—Calcutta, Bombay and Madras. The Committee considered therefore that there would be considerable advantage in obtaining quick results from the trial to destruction of specifications in the climatic conditions of Calcutta which are representative of the more humid parts of India. They also considered that the advantages in having the first test track designed and operated by a scientific staff already interested in these matters would be very great.

15. The Committee therefore recommend that a track should be laid down in Calcutta generally on the lines of and of the size of that at Bandoeng described in Mr. Meares' Paper No. 13 presented to the Inaugural Roads Congress. The track and equipment are now being designed. The test carriage wheel unit or units will reproduce as closely as possible the effect of iron shod bullock cart wheels and it is not considered necessary at the present stage to carry out tests under rubber tyred wheels or under a combination of the two. This will come later. The Committee feel that at the present stage many specifications have been evolved in India and elsewhere which can deal adequately with rubber tyred traffic and that the problem is to find one which will stand bullock cart traffic. It is recognised that the destructive action of a combination of the two is greater than either taken singly. But this applies to the greatest extent in the case of water-bound macadam and to a much lesser extent in the case of other specifications.

16. At the time of writing this report the design has not been completed. If possible, particulars will be furnished to the Congress at the time of meeting but in any event the recommendation of the Sub-Committee in its present form will, if agreed to by the General Committee and by the Congress, suffice as a recommendation to the Government of India to provide the necessary finance for the equipment of the track and so forth at Calcutta and for a second at Lahore if the local Government so desire.

17. *Supplementary equipment for Alipore.*—In order to obtain the fullest information upon the materials used in the test track and to enable the Alipore Test House to furnish more complete information than is at present possible regarding the qualities of stone aggregates and other road materials sent there to be tested in the ordinary way, the Committee recommend the addition of the following equipment to the existing Test House. This recommendation will be presented to the Government of India when the complete scheme including the test track is ready.

(1) *Dorry machine, vide* page 151, Volume II, The Road Makers' Library. "The Testing of Bituminous Mixtures". This machine provides for an abrasion test and supplements the Deval machine. The

Dorry test consists in cutting a cylinder 1 inch in diameter and 1 inch high of the stone to be tested and grinding the ends of it for a certain number of revolutions under controlled conditions against a circular steel disc fed with a standard sand. The loss of weight after the operation determines the co-efficient of hardness.

(2) *Page impact machine*.—This machine is used for testing toughness and also cementitious value. Toughness is tested by using a specimen similar to that used in the Dorry machine and cementitious value by using a specimen of the same dimensions composed of finely ground stone moulded, wet, and dried out in an oven. The sample is then subjected to blows by a plunger or hammer falling from increasing heights on to the end of the cylinder, the number of blows required to destroy any specimen indicating the hardness or cementitious value.

(3) *Apparatus for bituminous extractions*.—This apparatus enables the bitumen to be extracted from a sample taken from the road and the sample can then be analysed to see whether it tallies with the specification, the mineral aggregate examined for grading and the bitumen for consistency, etc.

18. *Method of conducting tests*.—The standard method of conducting tests of various road materials should follow as far as possible those adopted by the British Engineering Standards Association, or, failing such standards, those of the Road Research Laboratory at Harmondsworth or the National Physical Laboratory at Teddington.

VII. Standard Road Signs.

19. Owing to some difficulty in reaching complete agreement on the design of certain additional road warning signs the Consulting Engineer to the Government of India (Roads) decided to submit these to the Congress before advising the Government of India to recommend them for general adoption by Local Governments. The designs for two signs were, therefore, submitted in the first instance to the Technical Sub-Committee which recommends as follows:—

(i) Sign indicating depth of water over Irish bridges or causeways. The design recommended is reproduced at enclosure III hereto.

(ii) Sign indicating "Narrow Bridge" ahead. The design recommended is reproduced at enclosure IV hereto. This sign should be sparingly used and only in cases of real danger of two vehicles meeting on a blind bridge too narrow for them to pass each other.

VIII Standard Clearance for Bridges over Roads.

20. Another matter referred to the Sub-Committee in this way, was the necessity for standardising the dimensions under bridges passing over roads and the dimensions suitable. The Committee recommend as follows:—

(a) Under railway bridges over metalled roads or roads likely to be used by mechanical transport, the full horizontal formation width of the road and a *minimum* height of 14 feet.

(b) For tunnels the minimum width should be 20 feet and minimum height 14 feet.

IX. Earth roads and soil research.

21. At its second meeting the Sub-Committee expressed the opinion that something ought to be done to promote the further study of soils in their relation to earth roads and at the third meeting they considered certain specific proposals in this regard. This is a matter, however, in which the Committee feel that little or no progress is possible unless there is a strong local demand for the improvement of earth roads. In very round figures (details are not available for all States) it is probable that there are, excluding purely village roads, some 300,000 miles of road of all classes maintained by public authority in India of which possibly 80,000 miles are metalled or otherwise provided with a hard surface. Under no conceivable scheme of finance is it likely that the milage of metalled roads can be so increased within, say, the next ten years as to reduce the general importance of improving earth roads and in addition to the milage of the latter maintained by public authority there is a very large milage of village roads which are generally merely cart tracks. Much has been done in America to study soils in their relation to earth roads and road foundations; a certain amount of work has been done in classifying soils in the Punjab and a considerable milage has been improved; and as described by Colonel Wakely* at the Inaugural Indian Roads Congress, a number of earth roads have been developed and improved in the North West Frontier Province. In the latter case, however, and to a great extent in the Punjab, it has been found that as soon as these earth roads are improved traffic develops to an extent which is often beyond the capacity of the earth surface and the road then has to be given superior surface or it falls into as bad a state as ever and traffic is again discouraged. It must also be remembered that the type of earth road which has been developed in the United States of America has not to deal with anything so destructive as the tracking bullock cart and it is not too much to say that up to the present in no country in the world has an earth road been developed which will stand such traffic. Finally it must be remembered that in India while some earth roads are in charge of well organised district boards the tendency is to keep these roads outside the purview of the scientifically trained engineer and the first question is to what extent it is desirable and possible to approach the question from a scientific point of view and invoke the aid of scientific knowledge in dealing with this problem.

22. The Sub-Committee are strongly opposed to a defeatist policy which would rest content with existing conditions. It has not yet been proved that the difficulties due to the present bullock cart are insuperable and that no improvement can be looked for until the loaded bullock cart at least has either been segregated from the rest of the earth road or has been separately provided for, *e.g.*, by means of trackways. Conditions of soil, climate, and traffic vary widely throughout India and the alluvial plains of the Punjab and the valley of the Ganges on the one hand, and black cotton soil on the other present very difficult but diverse conditions. Nevertheless the Sub-Committee feel that widely divergent as these conditions are, and with due regard to the desirability of local

* Paper No. 4.

experiment and research, the study of soils and the possibility of their improvement by blending or other treatments is so specialised a matter that it requires special study at first by one man. They think it will probably be necessary to create a special post for the purpose. They recommend with some diffidence that some officer be placed on special duty or some one be recruited for the purpose, firstly to study all available literature on the subject; secondly, to make a brief survey of what has been done so far in India and with what results; thirdly, to make a very rough classification of the more usual soils which have to be dealt with; and then, after a period of study abroad, to recommend and, if necessary, supervise a series of experiments in different parts of India to determine what can be done and at what cost, to improve existing roads by scientific treatment. This officer would eventually have to be equipped with a certain amount of laboratory apparatus for the analysis of soils and so forth. If success were achieved with certain soils it might then be necessary to employ a chemist also to work in collaboration with the special soils officer and suggest possible methods of treatment of inferior or salt-impregnated soils. The Sub-Committee feel that the whole question is one upon which full discussion by the Congress and the expression of opinions from different Provinces is most desirable and indeed necessary before any cut and dried plan can be formed, but they strongly recommend that the matter should be seriously considered and that, if in the view of the Congress any benefit is likely to result in the creation of a special post, the Government of India should be approached to provide the necessary funds from the provision for research and intelligence in their Reserve in the Central Road Fund.

X. Standard bridge loading.

23. A certain amount of preliminary work has been done on this question but the Sub-Committee has not been able to examine it, or to deal with the matter at all. They recommend that the creation of a special bridge loading and design sub-committee of the Congress should be considered in the discussion of the Papers on bridges being presented at the second session, Bangalore.

XI. Library.

24. The Sub-Committee consider that, as part of the organisation of the Congress, there should ultimately be a reasonably complete library suitably catalogued for easy reference on any road problems which may arise. For a start they suggest that as a nucleus the library of the Consulting Engineer to the Government of India (Roads) should be kept up to date and be catalogued. The catalogue would be issued to all members of the Congress who should be allowed to borrow books for a reasonable period or could ask for information to be looked up on specific points. The opinion of the Congress is invited on this proposal.

ENCLOSURE I.

Conversion Table.

(*vide* para. 8 of the Report.)

Assuming specific gravity=1.

(*a*) Surface treatment.

Gallons per square yard.	Square yards per gallon.	Pounds per 100 square feet.
1/8	8	13·9
1/6	6	18·5
1/5	5	22·2
1/4	4	27·8
1/3	3	37·0
1/2	2	55·6
3/4	1 1/3	83·3
1	1	111·1

(*b*) Mixtures.

Gallons per cubic foot.	Pounds per cubic foot.
1/8	1·25
1/4	2·50
1/3	3·33
1/2	5·00
3/4	7·50
1	10·00

ENCLOSURE II.

Form of record of experimental Road Work.

(*vide* para. 6 of the Report of the Technical Sub-Committee.)

1. Name of road.
2. Milage and precise limits of experiment.
3. Length.................Breadth ....
 and area..................of experiment.

 Height of embankment above :—

 (*a*) Ground level.
 (*b*) Normal high flood level.
4. Dates of commencement ....
 and completion ....
5. Nature and material and condition of old road *including sub-grade and soling* and how treated.
6. Specification, or Specifications with particulars, of the areas to which they apply to be attached to this form.
7. Temperature :—

Maximum.		Minimum.	
Dry bulb	Wet bulb.	Dry bulb	Wet bulb.

 (1) During construction.
 (2) Range during a year.

Rainfall :—

(1) During construction.

(2) Yearly average.

9. Quantities and kinds of aggregate used with rates and cost.

10. Quantities and precise descriptions of binder used, with rates and cost.

(NOTE.—The penetration of bitumen and its origin, the viscosity of tar and its origin, the percentage of bitumen in cut backs and emulsions should always be stated.)

11. Labour costs with analysis of number of different classes of labour men—days and daily wage of each class.

12. Description of plant used.

13. Total cost for jobs, and cost per 100 square feet for :—

(1) Aggregate.

(2) Binder.

(3) Labour.

(4) Operation of plant.

(5) Total.

14. Mean yearly traffic per 24 hours; motor vehicles and bullock carts separately :—

(1) Numbers.

(2) Total estimated weight.

15. Nature and condition of road side avenues. To what extent is the work shaded from sun, protected from weather generally, or subject to drip from the trees.

16. Append to this form a brief description of the execution of the work and note any special or unusual features.

For *Enclosure III.*—Design* of "Flood gauges," to indicate depth of water over Irish bridges or causeways, see plate opposite.

For *Enclosure IV.*—Design* of "Narrow bridge" sign, see plate facing page 186.

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* *N.B.*—These designs have since been included by the Government of India in their standard series of designs of Road Warning Signs. The number shown above each design is its number in the standard series.

BUSINESS SESSION (CONTINUED).

Discussion.

Chairman: The first item on the agenda is to receive the Report of the Council and adopt resolutions thereon.

Mr. K. G. Mitchell: Chairman and gentlemen, I beg to move the first resolution, to the effect that:

> "This Congress resolves that the Memorandum of Association,* Rules, Regulations and By-Laws as recommended by the Council be adopted."

I do not propose to make a speech, but as I have drafted the documents in question if anyone has any questions to ask, I will answer them. The general outline of the constitution follows what was decided last year at the General meeting at Delhi has been in your hands for some time. There is nothing more which I have to say on it.

Rai Bahadur A. P. Varma: I second the resolution.

Chairman: Has anyone anything to say on the resolution?

Mr. Shanker Rao Panje: I have a slight amendment to suggest on this resolution. In Para 2, Page 1 of The Memorandum of Articles of Association a reference is made to the objects of the Society. The paragraphs which refer to the means to be used in attaining the objects read as though they are the end in themselves. Therefore, I suggest the introduction of a phrase "as a means to achieve these ends periodical meetings will be held" etc.

Mr. K. G. Mitchell: The Memorandum was drafted in that way only originally. But when we submitted the draft to him the Solicitor to the Government of India suggested that it is usual, in Memoranda of Articles of Association, to include among the objects everything that a society proposes to do even though some of those things are not an end in themselves but only a means to the end.

Mr. Shanker Rao Panje: Then I would withdraw my amendment.

The amendment was, by leave of the Chairman, withdrawn.

Chairman: I now put the resolution to vote. Those in favour may raise their hands.

Chairman (after a show of hands): The Resolution is now passed unanimously.

Mr. S. G. Stubbs: I beg to move the second resolution which is to the effect:

> "This Congress resolves that the Report† of the Technical Sub-Committee as amended and recommended by the Council be accepted and that the Council be authorised to take action thereon."

Mr. C. P. M. Harrison: I beg to second this resolution.

Chairman: Has anybody anything to say on this resolution?

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* See pages 166 to 174 *ante*.

† See pages 175 to 185 *ante*.

Mr. S. G. Stubbs: I recommended that the Report of the Sub-Committee be accepted. There is, however, a slight alteration to be made in Enclosure II of the report. In Item 5 thereof, the wording should read:

> "nature and materials and conditions of old road treated including sub-grading and soling and how treated."

Mr. K. G. Mitchell: Mr. Stubbs' amendment is designed to amend enclosure II of the Report of the Technical sub-Committee which describes the forms for recording the experimental road work. The wording should read as stated by Mr. Stubbs. He has added the word "materials" after the words "nature and" and the words "including sub-grading and soling and how treated" at the end.

Mr. C. P. M. Harrison: I have great pleasure in seconding the resolution as it has been amended.

Chairman: Has anyone any objection to accepting the amendment?

The amendment was then adopted.

Mr. A. Lakshminarayana Rao: I request that a test track be set up in Madras for water bound macadam roads, retaining at Delhi the test track for cement concrete and asphalt roads.

Reasons:—Total milage of metalled roads in India is said to be 80,000. Madras Presidency alone has 19,719 miles (*vide* page 7 of the "Scheme of Road Development in Madras Presidency" by Mr. A. Vipan). Thus Madras alone contains 25 per cent. of the metalled roads of India and Engineers are finding the need for this test track. In the last session of the Madras Local and Municipal Engineers' Association, a request was made to provide facilities for testing the road materials. I therefore request this Congress to help us. The initial outlay is not likely to be more than a few thousand rupees.

With reference to the road sign for causeways etc., it is desirable that the red painting be continued to the top or that 2 red lines are painted in the borders to indicate the danger of crossing the causeway when water is flowing in the red zone. Black cannot be seen in floods as the foam of floods is likely to cover it. Next a notice may be written on the top that "It is dangerous to cross the causeway when water level touches red lines". This will save the authorities liability for damages when careless persons cross the causeway rashly when water is flowing deeper than one foot and come to grief.

K. S. Ramamurthy: I second the amendment.

Mr. K. G. Mitchell: The temptation is too great to resist and I must draw your attention to the fact that Mr. Lakshminarayana Rao who has throughout the discussions criticised reference to bullock carts as being destructive, now wishes to test in different localities the destruction caused by the bullock carts on water-bound macadam roads. This is a subject that will have to be placed before the Council and the Technical Sub-Committee who will deal with it.

As regards the second part of Mr. Lakshminarayana Rao's proposal, I concede that there is a good deal to be said in favour of placing two red lines, one on each side of the sign-post. This is a very good suggestion and will be considered by the Council.

Mr. Thirumalaiswamy Ayyar: I suggest that in the Technical Sub-Committee's Report Page 185, Item 14, the maximum weight of the bullock cart or the motor vehicle be indicated under the head "mean yearly traffic for 24 hours". This detail is, I consider, quite indispensable for arriving at conclusions generally in regard to road surfaces etc.

Mr. T. R. Ramaswamy Ayyar: I second this amendment.

Mr. Bashitam: As I understand the position, this Congress has been asked to recommend to the Government of India the provision of a test track in Calcutta and another somewhere else preferably in North India. The previous speaker spoke in favour of providing what I may call "peripatetic" tracks in different places in a Province. That surely is a matter for the individual provinces concerned and this Congress should not lend the weight of its authority in support of any such recommendation to the Government of India.

Chairman: I understand that no definite decision has been reached as regards the location of the Test Track. It will perhaps be more satisfactory for the mover of the amendment if the resolution contains no mention of the location of the Test Track.

Mr. Lakshminarayana Rao: In that case I withdraw the first part of my amendment which refers to the Test Track and will move only the second part which relates to the road sign at causeways.

Chairman: The second part of the amendment, which relates to the flood-gauge sign, I would like to submit for the consideration of this house. Will you please vote on this amendment?

The amendment recommending the flood-gauge sign of the type suggested by Mr. Lakshminarayana Rao was then carried unanimously.

Chairman: The third amendment on the resolution, that moved by Mr. Thirumalaiswamy Ayyar, refers to the entry of the maximum load in Item 14, Page 185, of the Technical Sub-Committee's Report. I think it is a very reasonable suggestion. Has anyone any objection to it?

None objecting, the amendment was put to the vote and carried unanimously.

Chairman: I will now put the second resolution moved by Mr. S. G. Stubbs and as amended, to the vote.

The second resolution as amended was then carried unanimously.

Chairman: I now move that—

> "This Congress begs to offer to His Highness the Maharaja of Mysore its most hearty thanks for his magnificent hospitality to the members who took part in the delightful tour to Mysore".

It is not necessary for me to make any speech on this resolution and I recommend it for your acceptance.

Mr. K. G. Mitchell: I second it.

The resolution was carried with loud acclamation.

Chairman: I beg leave to move that—

> "This Congress begs to offer to His Highness the Maharaja, the Dewan and the Government of Mysore, its most hearty thanks for their hospitality in inviting the Congress to meet in Bangalore and for the admirable arrangements made in connection therewith."

Mr. G. B. E. Truscott: I second this resolution.

The resolution was carried with loud acclamation.

Major W. B. Whishaw: I have great pleasure in moving that—

> "This Congress desires to thank Diwan Bahadur N. N. Ayyangar, Chief Engineer and Secretary to the Government of Mysore, Public Works Department, and his staff for the untiring thought and energy they have devoted to the arrangements for the Congress tour and meeting."

Sardar Bahadur Sardar T. S. Malik: I second this resolution. In doing so I wish to point out that it is a matter of great pride to us all that our brother officers have been able to manage this show so wonderfully well. In touring about we have not only tasted the hospitality of Diwan Bahadur N. N. Ayyangar but also of his subordinate officers. He and his co-workers have loyally carried out their work and done everything to make our tour as comfortable as it could possibly have been made. We should not also forget the tender cocoanuts we had on our way! (Laughter). If you permit me to say so I would say "all the arrangements were d—n good!" (Laughter and cheers).

The resolution was then put to vote and carried with acclamation.

Rai Bahadur S. N. Bhaduri: I have great pleasure in moving the following resolution—

> "This Congress resolves that the hearty thanks of the meeting be accorded to Amin-ul-Mulik, Sir Mirza M. Ismail, KT., K.C.I.E., O.B.E., for his opening address and that the same be incorporated in the proceedings."

Mr. A. P. Varma: I second this resolution.

The resolution put to the house was carried with acclamation.

Rai Bahadur Sunderlal: I have great pleasure in moving that—

> "This Congress resolves that a hearty vote of thanks be accorded to the Committee of Management of Sir Puttanna Chetty Town Hall for their kindness in placing the Hall at the disposal of the Congress for holding its meetings."

Col. G. E. Sopwith: I second this resolution.

The resolution was carried with acclamation.

Election of four members of Council.

The Congress then proceeded to elect four members of Council as provided for in Section II 1 (9) of the Rules and Regulations of the Society.

The following names were proposed for election and duly seconded:—

Mr. W. H. Rowlands.

Mr. Bashiram.

Mr. N. V. Modak.

Mr. A. Nageswara Ayyar.

Rai Saheb K. C. Gue.

Brig. E. C. Walker, and

Mr. M. G. Banerjee.

A ballot was held and after the counting the Chairman announced the following names as those of the elected members.

Mr. W. H. Rowlands.
Mr. N. V. Medak.
Brig. E. C. Walker; and
Mr. S. Bashiram.

Election of Auditors.

The Congress then proceeded with the election of auditors for the accounts of the year ending September 1936.

Mr. C. D. N. Meares: I would like to propose approaching Mr. Sahgal, Secretary of the Accountancy Board, Government of India, with a view to getting him to act as honorary Auditor. He is a Chartered Accountant and before taking up Government appointment was doing private work as an auditor.

Mr. Hughes: I second this proposal.

The Congress adopted this proposal unanimously.

Correspondence.

In the discussion at the business session on Item VII of the Report of the Technical Sub-Committee, it was suggested by Mr. Lakshminarayana Rao, District Board Engineer, Cuddapah, that the flood gauge proposed by the Technical Sub-Committee was defective in that when submerged to a depth of more than 3 feet it would appear merely as a white post and, as the use of white guard posts is not uncommon, a traveller might be unaware that this particular post was part of the standard gauge and that in consequence there was more than 3 feet of water over the gap. He suggested therefore (*a*) that the gauge should be painted with a red line on either side from 3 feet to the top and (*b*) that a notice should be put up over the gauge to the effect that it is dangerous to cross the causeway when the water level touches the red lines, *i.e.*, is over 3 feet in depth. Mr. K. G. Mitchell, Consulting Engineer to the Government of India (Roads), undertook to place the proposal before the Council of the Congress.

2. The matter has been duly considered by the Council by postal referendum and they have decided that the notice board suggested by Mr. Lakshminarayana Rao is redundant as it obviously is dangerous to cross a causeway with more than three feet of water over it or even one foot if the velocity is high. They however agreed that the top 3 feet of the gauge should be marked in some way so as to distinguish it from an ordinary white post and decided that the design proposed by the Technical Sub-Committee should be amended by the provision of a single red line down the centre in the top three feet.

3. The design of the "Flood Gauge" thus amended by the Council and that of the "Narrow Bridge" sign endorsed by the General Body were then forwarded to the Government of India by the Secretary, with the suggestion that they should be circulated to local Governments for adoption. The Government of India have since included the designs in their series of standard designs of road warning signs and have circulated copies to all local Governments, Minor Administrations, Political Officers, etc., suggesting their adoption. Copies of the designs, as finally adopted, have been incorporated in these proceedings.

R. L. SONDHI.

Second day, Friday, January 10, 1936.

GROUP 5:—EARTH ROAD IMPROVEMENTS [PAPERS Nos. 23 (a), 23 (b) AND 24].

CHAIRMAN: RAI BAHADUR CHHUTTANLAL, I.S.E.

The following paper was taken as read:—

Paper No. 23(a).

ROADS IN RURAL AREAS (VILLAGE ROADS).

By

Hony. Capt. Rao Bahadur Choudhry Lal Chand, O.B.E., M.L.A., Member of the Standing Committee for Roads of the Central Legislature.

I regard it a privilege to have this opportunity of putting in a few words on behalf of the 90 per cent. of India's population living in villages, before this august body of Engineering Experts. I confess, I have no technical knowledge of road building nor am I supposed to dwell on the sort of material to be used for the construction and maintenance of roads. I wish only to draw your attention, and through you, that of the Government of India, to the great necessity of giving villagers, their fair share of attention; and my remarks will be confined to village roads as distinguished from what may be called Trunk roads.

2. Rural problems have been my hobby during the last 20 years of my connection with public life in India, and while on the one hand, I am aware that villagers are not getting their fair share in Government jobs and Councils, on the other hand, I feel convinced that villagers are not being given enough attention in regard to the beneficient services, such as Education, Medical aid, and Communications. It was, therefore, my desire since last year to bring the question of village roads to your notice, and I am grateful to the Honourable Member for Industries and Labour for giving me this opportunity of addressing this assembly. For those of us who do not get opportunities to know rural conditions, it is really difficult to realise the appalling conditions in which some of the villages are placed. There are some villages which remain cut off from civilised world for a large part of the year, while a still larger number is closed for any wheel traffic all the year round, and there are villages where fast traffic is practically unknown. The problem of 75 per cent. of the people, actually living upon agriculture, who have to cart their produce to markets and to railway stations, is not an easy one to solve and if we take into account the other 15 per cent. consisting of labourers and artisans living with these agriculturists in villages, the figure goes up to 90 per cent. and no scheme for the improvement of communications is complete unless we make necessary provision for these teeming millions to be brought into touch with the improvements in wheel traffic affected by Science. It is with a view to bring this aspect of communications in India to the forefront, that I have ventured to come before you with my humble contribution. The nature of my subject is such that I cannot give any figures, and thus my address will serve as a variety, among the learned

papers full of mathematical calculations that we read before you during this session. But I hope I shall be excused, if I claim some personal knowledge of the conditions of village roads, and also of the fact that very little attention (if at all) has been paid by Government, to the problem of giving villagers proper communications by improving the village roads.

3. **What are village roads?** The term "village roads", includes all the *kacha* roads running through the country. They may be classed as (i) District Board *kacha* Roads and (ii) Village roads which are not the property of any local body, but are owned by villagers and have been shown in revenue papers as "Public thoroughfares".

4. **District Board Roads (*Kacha*).**—Class No. (i), are supposed to be maintained by District Boards and other Local Bodies; but as funds at the disposal of these local bodies are very limited, they cannot keep them in good condition, and in most cases the only interest these District Boards show, in some of these roads, is simply to exercise their right of ownership of trees, most of which grow spontaneously on both sides of these roads. Consequently, these roads are unfit for any wheel traffic except perhaps the country bullock-cart. Their importance, however, is very great as nearly all the agricultural produce of the country has to be carried along these roads, before it reaches either a trunk road or a Railway Station where there is a marketing *Mandi.* I may here refer to the great improvement effected on *pacca* roads in recent years. The old sandy *Kankar* roads have all been made dust-proof, and credit for this goes to the engineering profession, as this has been done without any appreciable increase in expenditure. The great research work that has been done in order to improve trunk roads, is most commendable to the authorities. But to my utter disappointment, I find that District Board roads whether *pacca* or *kacha* have not been keeping pace with the times. The only thing which Public Works Department has done for them, is to relieve these bodies of some of the more important roads connecting one town with the other. The *kacha* roads to which I was referring have entirely escaped their notice and are still in a hopeless condition.

5. **Village Roads which are property of villagers.**—As regards class (ii) roads, the less said the better. In most cases they serve as drains also and, as there is no one to look after them, they have been so narrowed that it is in some cases difficult even for bullock-carts to pass along these so-called roads. As these roads came into existence long before the science of engineering had been known in the interior of the country, they all take a zig-zag route, and the task of improving them becomes all the more desirable. Legislation is necessary to compel people, not only to remove the curves mentioned above, but also to widen these roads on some uniform basis. Villages have ceased to be mere hamlets and there are tracts where the population of individual villages is from 2,000 to 5,000, as in South-East Punjab and Delhi Province. In Western countries, each farm has a *pacca* road but here even villages of the size mentioned above, cannot boast of even a decent *kacha* road. The first thing in a new canal colony is always the provision of good communications. What a pity that even in settled areas of the country, this first element of civilisation is denied to them.

6. **Is it a case for special treatment?**—No. When I ask for the improvement of these village roads, I do not beg for any special treatment. My claim for expenditure on these roads rests entirely on merits. In the first place, there is the population consideration. I have already pointed

out that 90 per cent of the people of India live in villages. Eighty per cent of these are agriculturists or producers of India's raw products, while the rest also depend upon the agriculturists for their prosperity. We all profess to be well-wishers of agriculturists. "Rural Uplift" and "Rural Reconstruction" have been accepted as key-notes to India's prosperity, both by Government and the Opposition. It is, therefore, in the fitness of things that this learned body of Experts who are responsible for the progress of the country to a very substantial degree, should undertake to find ways and means, to give these villagers this first element of civilisation. Perhaps, it is known to all of us here, that there is a move from villages to towns. All villagers who secure some education, try to settle in towns, and as I am one of the guilty persons myself, having partly shifted to a town, I know why this is so. This is chiefly due to the difficulty felt in moving to and from the villages, and this tendency is proving a great hinderance in the uplift of the rural population. No amount of improvement in agricultural methods can be effected, so long as the villages do not become easily accessible, and, so long as village communications are not improved, the standard of life also in villages will not go up.

7. Secondly, villagers contribute largely not only to the general revenues of the country, but are the greatest users of motor buses. The old bullock cart used for attending fairs and marriage processions, has been replaced by buses or "lorries" and if we take into account the use of lorries in elections in rural areas, their contribution to the Fund at the disposal of the Road Board becomes significant. So, both from the point of view of numbers, as also from a consideration of contribution, villagers deserve increased attention.

8. Here, I gratefully welcome the presence of this item on the programme of "Rural Uplift" in some of the Provinces. For instance, out of the sum of one crore granted by Government of India for "Rural Uplift" to different provinces, no less than 12 lakhs is being spent on village roads as follows:—

		Rs.
Madras	... ...	4,50,000
Bihar & Orissa	... ...	6,00,000
Assam	... ...	1,00,000
N. W. F. Province	... ...	10,000
Delhi Province	... ...	10,000
Ajmer & Merwara	... ...	23,000
	Total Rs. ...	11,93,000

9. This is a very small item, but as we villagers feel satisfied even with small mercies, I must congratulate the authorities in the above provinces for having included village roads in their "Uplift Programme". I am sure the lead given by them will be followed by others also, and in future at least half the amount they spend on "Rural Uplift" will be devoted to the improvement of village roads. I also pray that the Road Board may earnestly include this item in its programme, and set apart a certain percentage of funds at its disposal for the improvement of village roads. Steps should also be taken to effect the proper legislation in

provinces. It is very difficult to give any suggestion in a short paper like this. But broadly speaking, I would make all class (ii) roads the property of District Boards on the lines of the roads, open spaces, etc. in a Municipal town. As soon as a Municipality is created, all roads and open spaces, etc., vest in them and it would be in conformity with their accepted principle, if the village roads become the property of District Boards.

10. **Effect of Rail-Road competition.**—Another reason for my plea for increased attention to village roads is, that ever since Rail-Road competition has begun, the extension of railways into the interior of the country has stopped, and attention has been concentrated on the improvement of main trunk roads, which are mostly running parallel to the railway lines, and development of the interior of the country is thus at a stand-still. So, unless the item of village roads is included in the programme of road development, it will take a long time before we get our turn for these roads. I, therefore, while apologising for the intrusion on your valuable time, appeal to you to give the subject your favourable consideration and translate your sympathies into action when you go back to your respective provinces. To those of you who are responsible for this Congress and for the administration of roads throughout India, I would address one word. Let the villagers have a proper share of your resourceful talents and when confronted with financial difficulties, remind your Governments that 'where there is a will, there is a way!'

Captain Rao Bahadur Choudhry Lal Chand, Mr. President and Gentlemen, I look upon it as a great privilege to have got this opportunity of addressing this august body of experts who are really the builders of civilized India. But it is only with mixed feelings of pleasure and diffidence that I stand here before you to put in a few words on behalf of the teeming millions of India living in villages, while introducing my paper on village roads. I feel pleased because the Government of India has shown a great courtesy to the Standing Committee for roads of the Central Legislature by extending the invitation to them and I take pleasure in the fact that they have selected me as their representative to speak of rural roads. But on the other hand I am diffident as it is not easy to speak before an audience of learned body of experts, particularly when one has to speak on a technical subject and has to take care to keep politics out of the speech. I hope you will kindly excuse my shortcomings and would look at what I say as the point of view of the general tax-payer for whose comfort you are supposed to be catering.

The proposal I have made in my paper to bring the village roads into proper order is very colossal and very important. It is colossal because here millions of miles are concerned. It will take the Engineering Department a number of years, many decades to complete the task even if they set in right earnest to make the village roads motorable. It is *important* because as is well-known to you, ninety per cent. of the population in India lives in villages and most of the taxes are derived from their pockets. They are the chief consumers in India and as such they contribute largely to the exchequer and therefore, if there is anything which is needed for them it is very important that their needs should not be thrown into the background. There is, however, one good thing about my paper and it is this: That I will not bother you with any statistics. Statistics there are none. Moreover there would be no complicated

formula to be shown to you on the black-board. The question is really so simple that even experts will be able to agree on this question. But before I come to my subject, with your permission, Sir, I wish to make some general remarks about the activities of this Congress.

I must confess that I came with some prejudices against the work of the Engineering Department, because, whether we admit or not, there is some adverse notion about the working of the Engineering Department and you will be pleased to learn as I am pleased to say, that I go away converted to your views (Cheers). I have tried to be present in most of your visits: It was difficult for me to follow the technical work that is being done on roads and to follow all the complicated things that are comprised in it but I am now in a position to answer one question which will be put to me by the non-official members of the Standing Committee for Roads at least. They will ask: "What are the aims and objects of this Congress as you have seen?" My reply would be simple. I am now in a position to say that I honestly feel that all of you gathered together here are trying to devise means to ensure that the tax-payer gets sixteen annas value out of every rupee that you spend on his behalf as his agents.

The Roads Congress has a great future before it. Federation is coming into being and British India and Indian States will be brought into closer contact and as soon as federation comes into being you will see many such bodies coming into existence as will enable British India and Indian States to co-operate with each other. I must congratulate Mr. Mitchell, the father of this Congress for his foresight and organisation (Cheers). He has been very careful in working out details but he has been more lucky in having secured Mysore State as the place of its second meeting. We in the Punjab used to take pride in our roads. And I still maintain that we in the Punjab are behind no province in respect of roads except Mysore. (Laughter.) I have known Mr. Mitchell for the last fifteen years; he has a fertile brain and a sympathetic heart but more than that he has a persuasive tongue. Let him persuade the Local Governments to ear-mark some of their finances for the improvement of village roads.

I was talking about Mysore. I personally have had some experience of an important State in Rajputana as I was for several years President of a State Council there. My idea of the Public Works Department in Indian States was confined to Shikari Roads to the supply of palace furniture, and to polo grounds. I am glad to find that Mysore is an exception to it. Mysore is a place of big works—not only big works but successful works. They are being worked so successfully that everywhere they gave minute details and from those details we inferred that economy was their watch-word. There was only one place where Mysore was seen going out of their way or leaving their principle of economy aside. It is in the treatment of their guests. (Cheers.) Nature is very kind to Mysore. They have got waterfalls, and mines and road material lying on the road, which facilities are not available to other places. With such able staff as we have seen here it was expected that they should make full use of it. I congratulate the Chief Engineer, Diwan Bahadur N. N. Ayyangar and his able staff on the successful working of all the Public Works Department works.

Now, coming to the subject, we have to bear in mind one thing: India is purely an agricultural country and a country of peasant proprietors,

not of big land-lords but of small land-holders. They cannot economically or easily take to machinery. They cannot dispense with their bullock-carts or their bullocks. For them the plying of bullock carts is a bye-profession—it is a necessity. They cannot keep themselves engaged all the 365 days of the year in their fields and they are plying carts for hire as well as for bringing their own goods to the market. They are a real necessity for them. And, therefore, all talk of driving out the bullock carts is, I think, unsuitable to Indian conditions.

Mr. Lakshmi Narayana Rao, one of the members who spoke this morning, has given very interesting figures. I am not, as I said in the beginning, taking the political aspect of this question. Otherwise I would stand on stronger grounds than this. What is democracy? Democracy means that people's wishes should prevail and what are the people of India? They are the millions that are living in the villages. You cannot drive them out; you cannot drive their carts out; all that you can do is to make these roads suitable for them, to the carts and the cars. If it were a question of driving out one of the two, then I think, the car will have a very weak case. In the Punjab we have these controversies now and then when a public works department road and an irrigation canal cross each other, the question arises as to who is to maintain the bridge and the question of priority comes in. And mostly the question is decided on the sole principle:—"who came here first?" The last comer is burdened with the maintenance of this bridge. If that principle were to be applied here then you can just imagine what will be the fate of the car as against the cart.

Let us take the economic view of the question: We all visited an out-of the way place near Mandya; there was only a five-mile *pacca road* leading to a small village. Diwan Bahadur N. N. Ayyangar very lucidly pointed out to us that before the small road of five miles came into existence it was impossible for the people there in spite of sufficient water being available to grow sugarcane because they could not carry their sugarcane to the factory that was in Mandya. Simply by giving them a five mile road, the acreage of sugarcane has gone up, and the peasants there can easily take their produce to the factory which is run for ten months in the year, a feature which is unknown either in the United Provinces or in any other provinces where there are similar sugarcane factories. In our part sugarcane factories are run only for four months in the year. It is so much a benefit to the peasant. In the absence of road facilities it will be impossible for them to bring their produce to the factory in the rains and both the producer and the manufacturer would have suffered. Not only this: the man produces more cane, he gives work to the factory, the factory makes profits which gives work to the labourers and all combined make more purchases and give an impetus to other industries also. So this aspect of the village roads should always be borne in mind. I am glad Colonel Sopwith has brought this out in his paper very lucidly. He has pointed out that making of village roads is an investment for the State; because although the State may not gain anything directly, yet indirectly the State gains in the prosperity of the people. If the people are prosperous they pay more taxes and, in the case of agriculturists, arrears of land revenue will be unknown. So for the State it is an investment. Colonel Sopwith gave an example of a road where the agriculturists were making some profit,

and the story has been told to him by a Minister of the Punjab Government. I have a similar example to give on my own testimony. There was *a piece of katcha road* in my district, say 14 to 15 miles which was needed to be converted into a *pucca road*. There were no funds with the District Board. As I was a member of the Provincial Communications Board I had free access to Mr. Mitchell who was in charge of the Communications Board then. I knew his weaknesses—one of his weaknesses is that he always wants to oblige his friends. My District Board approached him through me and he gave us Rs. 80,000 in a lump sum for that road, but not before he had very carefully scrutinised the gain to the people. That road has been in existence for the last fifteen years and you can imagine the gain when I say that every farmer is making at least three annas per maund over the produce that he sends to the market. It was impossible for country carts to pass along that road which was sometimes sandy, sometimes full of water. Now what do we see? After every fifteen minutes there comes a lorry and there are very many cars plying for hire on that road. It has become an inter-provincial road connecting the United Provinces and the Punjab. There are other cases also. The money spent on village roads, I say, is an investment for the State.

Sir, my proposition is a simple one. It is that Government has not been doing anything in that direction and that all the tax has been devoted to *pucca roads* to link up big cities and big towns and no scheme has been put forward or undertaken by the Government to link up villages or to bring them nearer *pucca roads*. Mysore again, has shown the way to us. The other day I went to the Kolar Gold Field mines. On the way I was surprised to find roads some *katcha* and some *pucca* leading to villages on either side. As I was interested in this question I motored down to one village and made enquiries. I admit that they have not gone very deep and there are yet many villages which are not accessible by wheeled traffic. But the way in which they have made a start is simply creditable. They have thus shown the way to the rest of India and deserve our congratulation. I want simple tracks to every hamlet to take in wheeled traffic there. My habits of civilization are very simple—I do not mind dust—I am not so sensitive as to be offended by slow obstructions. I do not require a constable at every turn to stretch out his arm for my convenience. I won't kill a man if he has not developed what is called the "Road Sense" and does not get out of my way easily. The maintenance charges of my roads will be negligible. I hope you will not deny this. I may tell you one thing that the peasant may not have his road-sense developed but one sense has certainly been developed in him. It is this. He realises that the money you spend comes from his pocket and if you go on spending it for the rich alone he will give trouble. You may have good track roads in the cities but he will not be easily pitched on to *katcha* berms. Such suggestions are simply preposterous. Agriculturists are called the backbone of the country. Is the backbone called the backbone simply to bear the burden?—to bear the load of taxation? and won't you give him anything to eat, to keep that backbone strong? You should prepare a programme for village roads. The Punjab problem which I know very well, is simple enough. In the Punjab colony districts we have got very good *katcha roads*. For every village there is a *katcha road* and that is enough. In another district the roads are there but they are very narrow and they are in a zig-zag condition; they need to be straight-

ened and it is for the Public Works Department to bring forward legislation before the local Government to make it easy for them to acquire lands. In some of the districts in the Punjab, consolidation of holdings is about to begin. They will lay the whole district into squares. It is being done by the Revenue Department and here is a golden opportunity for the Public Works Department to co-operate with them and make roads as they like because the present roads will have to be given up in any case. I hope Mr. Mitchell will remember that in 1924 he gave Rs. 24,000 grant from the Communications Board to one district alone where consolidation of holdings was going on. I have not seen what was done later on or how that money was used. But similar grants could be made for district roads. for the straightening and widening of these roads.

The question of funds is a real difficulty everywhere. We are told, as I was told elsewhere, that this was a question of policy. Let the Government frame its policy in regard to village roads and they will have it. The Government has already admitted its importance. The Honourable Sir Frank Noyce while addressing this Congress in December 1934* said "Individually rural roads may not carry much traffic but collectively I would remind you that they carry the whole of the agricultural produce of the country before it reaches the metalled road". Proceeding further he said "Steps are being taken to organise and improve the business technique of marketing, but the improvement of transport facilities rests with you". Again, "the possibilities of motor transport to serve rural population are immense. but can never be fully developed so long as it cannot reach important villages, and is confined to metalled roads at some distance from them " So the Government has shifted the burden on to the engineers and it is for you sir, to approach your local Governments or the Central Government or Durbars, as the case may be, for funds. I do not know of any case where a case may have been put up to any local Government for the metalling or straightening of these roads or making them motorable or serviceable for wheeled traffic, and where the Government may have refused. Not one case can be cited. Therefore, it seems that the tradition has been to go along *pucca roads* and it is *pucca roads* that receive first attention.

Now I will ask you the Chief Engineers of the Provinces to make it a rule as was done by Mr. Darling, Registrar of Co-operative Societies, in the Punjab that every young Sub-Divisional Officer or young engineer shall spend at least 15 nights in an out-of-the way village and the problem will be solved. He will have to go there and he will make proposals which will come to Government and the money will be sanctioned. Rural uplift has become the watchword of the day. What is the uplift of the rural classes unless you give them the first element of civilization, these roads? They do not want pucca roads—they want only tracks where simple wheel traffic may go.

I would make one suggestion to Mr. Mitchell. Let him show his next congress activities to the Finance Member of the Government of India and let him call in more members of the Standing Finance Committee and I am sure he can lay claim to the whole of the petrol tax (hear, hear), which is his by right.

I have to thank you for the patient hearing you have given me and for accommodating me all along. I hope by this time next year when this assembly again meets each one of you will be able to give an account

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* Progs. of the Inaugural Indian Roads Congress, December 1934, Vol. I.

of your activities in this line. With these words, Sir, I introduce my paper [Paper No. 23 (a)].

The following paper was then taken as read:—

Paper No. 23 (b).

GRAVEL ROADS.

By Diwan Bahadur N. N. Ayyangar, B.A., L.C.E., M.I.E. (Ind.), I.S.E. Chief Engineer of Mysore.

The development of the road system in Mysore is just a century old. Prior to 1831, Mysore had only a few unbridged roads maintained in an unsuitable manner, and systematic road-making was started during the British Administration from 1831 to 1881, when a few trunk, and *taluk* roads were opened with some bridges at a cost of about a crore of rupees. Since the Rendition to the Mysore Durbar in 1881, over four crores of rupees have been spent on an orderly programme of trunk roads and feeder roads with bridges across the major streams. There is today an excellent net work of 7,092 miles of road of which 3,966 have a metalled surface in an area of 29,475 square miles giving 24 miles per 100 square miles. (Corresponding figures for the neighbouring provinces are 20 and 22 for Madras and Bombay.) These roads may be broadly classified as (a) trunk roads, mostly metalled surface, establishing through communication between the east and west coasts and connecting the District Headquarters and other important towns, and (b) feeder roads between less important towns and villages.

2. While the needs of the towns have been fairly met, we have touched only the fringe of the problem relating to village roads. There are, in Mysore, 19,421 villages and access to most of them is by narrow cart tracks, the maintenance of which is, at present, nobody's concern. These tracks are merely two or more lines of ruts worn down by age, full of hollows, strewn over with boulders and often passing through narrow lanes and crossing 'Nalas' through difficult ground. A very large number of villages have thus been isolated from the markets. The first step towards rural development lies, therefore, in establishing easy communication between adjacent villages and the nearest highways.

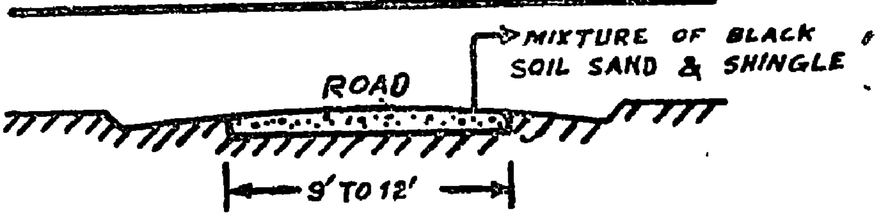
3. Assuming, roughly, an average length of 2 miles per village, for connection with the thoroughfares for communication between the neighbouring villages and for the conveyance of produce from the villages to the markets, we have yet to make roughly 38,842 miles of new roads. This is, on the very face of it, a formidable problem, unless we resort to a far cheaper, quicker and fairly efficient method of road-making, than the present macadam road. The solution for this is the gravel road. Good stony gravel is readily available all over, in almost inexhaustible quantities and the gravel road is the cheapest in first cost as well as in maintenance. It preserves a hard, smooth and pleasant surface in fair weather and, if made of the right kind of stony gravel, also keeps firm under ordinary rainfall conditions.

4. There are eight District Boards in the State and if each Board does on the average 4,855 miles, it means work for nearly 96 years to come at the rate of 50 miles of new road a year. This enormous amount of new work and the subsequent maintenance cannot possibly be carried out by ordinary human labour. It can only be successfully handled by adopting efficient modern methods of quick construction with machinery, such, as tractors, scarifiers, road graders and rollers. It is further necessary that some recognised un-official body like the Indian Roads and Transport

Development Association should take up this question and carry on the propaganda for the District Boards to tackle this problem of village roads actively and persistently.

5. The best variety of gravel available in the State is the reddish ferruginious one from parts of Tumkur, Kolar and Hassan Districts containing grit or stony material and clay in the proportion of 2:1. It is found by experience that the limit of grit should be 70 per cent for getting a good hard, well drained and smooth surface. There are no special difficulties in the construction of these roads except in black cotton soil tracts. In such cases, a coat of 4½ to 6 inches of sand and shingle should first be laid, mixed well with the black cotton soil, barrelled, watered and rolled.

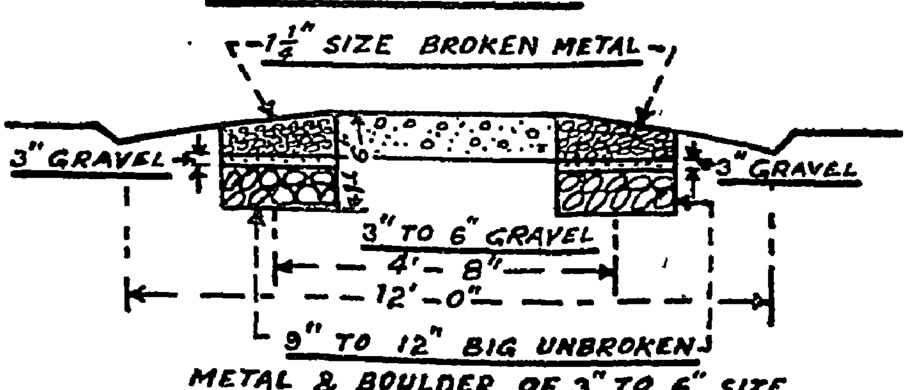
ROAD IN BLACK COTTON SOIL



This mixture of sand and shingle and black cotton soil answers the purpose of natural gravel fully. The cost of making such roads would be about Rs. 500 per mile in ordinary country and up to Rs. 1,500 in black cotton soil. The maintenance charges would be Rs. 50 to Rs. 100 per mile. If by mobilising all the resources from Government grants, District Board and village *panchayet* funds we can programme to spend on our village roads during the next fifty years, about the same amount spent on roads by the State during the last fifty years, namely Rs. 4 crores, it will be possible to start the work on an organised basis and give relief to the agriculturists in half a century. The work has to be started immediately in view of its importance to the villages.

6. Where traffic is heavy, it will be necessary to give special treatment to that portion of the road surface which bears the maximum strain of traffic, *i.e.*, under the wheels. It will not be long before these village roads should be made capable of withstanding the heavier and more continuous and all weather motor traffic as well. If, therefore, the two wheel tracks could but be strengthened with boulder bedding and water-bound macadam, the damage to roads could be prevented and the inconvenience to motor vehicles would be removed.

WHEEL TRACK



7. For forming these wheel tracks, it would be enough in the case of gravelled roads to cut open trenches 1½ to 2 inches wide along the tracks, to a depth of 12 to 18 inches according to the nature of the subsoil and fill in the bottom 9 to 12 inches with boulders of 3 to 6 inches size. After handpacking the boulder metal and covering with about 3 inches of gravel, the top 3 inches may be laid with 1¼ inch size quartz or field metal (available closeby in the surrounding villages just for the picking) watered, consolidated and finished with a thin layer of gravel. The remaining width of road, excepting the tracks, may be surfaced with 3 to 6 inches of gravel and rolled.

8. These metalled trackways or gravelled roads have been tried with success in the irrigated area under the Irwin Canal round about Mandya. The gauge of bullock carts varies from 4 feet to 4 feet 3 inches and the width of tyre 2 inches, while the gauge of motor lorries varies from 5½ feet to 6½ feet. After a preliminary experimental work, the tracks are laid 2½ feet wide and 4½ feet between the centres, so as to accommodate not only cart traffic but also motor vehicles. These "track" roads have been in service for over a year and are found to be satisfactory notwithstanding the fact that the roads run in irrigated fields where the level of sub-soil water is high and ground also soft.

9. The grants for gravel roads are naturally low. It is not a sound policy to spend the grants in metalling short stretches in a gravel road and leave the rest in a state of disrepair. It is far more satisfactory to spend the money in maintaining the entire length, on a gravel basis, as satisfactorily as possible. If natural stony gravel of correct proportion is not readily available, mixtures can be made on the lines indicated in the note attached as an appendix to this paper. These gravel roads can be later on metalled and the metalled road even treated with the expensive tar or bitumen, when conditions change and traffic demands justify. No work done now has to be undone, but on the other hand, a solid foundation will have been laid for future progressive development.

10. *Conclusion.*—During the past fifty years, 2,200 miles of roads with bridges have been opened at a cost of Rs. 4 crores. The programme of village roads to be taken up during the next half a century does not necessitate any heavy expenditure under bridges as only small "nallas" have to be negotiated either by culverts or by causeways. We have seen that gravel roads are the best suited for the needs of the villagers and it will be easy to lay nearly 400 miles of gravel road a year, if necessary, using mechanical contrivances for speedy work. On this basis in fifty years, we will have 20,000 miles of new road or roughly 1 mile per village. The yearly grant required will be Rs. 4 lakhs. At present, the Government is giving some grants. The District Board is spending some money and the village *Panchayets* are doing some work. If all the resources of all these bodies are pooled and a consolidated programme drawn up in the first instance for ten years, we will be having a net work of roads connecting villages of which any country may be proud. The execution of the programme may be entrusted to the Public Works Department and a rigid adherence to the scheme enforced, in order to prevent any frittering away of money, as it is all important to have a thorough organisation and a continuous policy.

11. Though the gravel road is a minor type of road, its economical and satisfactory working demands a considerable amount of judgment and experience. But one or two officers having these qualifications can give timely advice and guidance to a large number of men working under them all over the province.

APPENDIX.

The annual maintenance grant for ordinary gravel roads varies from Rs. 50 to Rs. 100. It is sometimes seen on a stretch of gravel road, that attempts are being made to metal a few furlongs here and there, out of this small grant. The result of this is, that most of the maintenance money is spent on a short bit and the remaining portion gets into bad condition for want of money and attention. It is not, therefore, a sound policy to attempt to metal gravel roads unless adequate funds are available. The proper thing to do is to spend the amount on the whole road and try to keep it in as good a condition as is practicable with this grant.

2. It is found from experience that the best gravel is that of a red ferruginous variety, which contains two parts of gritty material, such as quartz and one-third of clayey material. If any road with a firm subsoil has got this gravel material on it, properly sectioned (cambered) at, say, 1 in 20, watered and rolled, it will make a hard surface and will remain in an excellent condition in fair weather and in the rainy season also the surface will remain fairly firm. So, our attempts should be to find such a kind of gravel containing two-thirds proportion of grit and one-third clay and use it on the road; but in practice it will be found that, along the roadside from place to place this varies very considerably. Also there are numerous nalas, streams and rivers crossing our roads and they oftentimes contain at the convex banks of the bends, excellent sand, shingle and gravel on either side of the road. If we mix the natural gravel obtained and the sand or shingle that is obtained in the nalas in the proper proportions, it is the easiest thing to get a mixture as would finally contain two-thirds of grit and one-third of clay. In order to get this correct proportion, the following method may be followed:—

Take the natural gravel that could be got. Fill it, say, in a kerosene tin 10 inches high or of any suitable height. Add plenty of water and stir and throw out gently the muddy water without losing any grit. Repeat this four or more times till you get the grit free from earth or clay. Then measure the height of grit left. Find the ratio between the cleaned grit and the original gravel. Call this ratio G per cent grit. Let X be the quantity of sand and gravel in percentage to be added to this gravel to get the correct proportion of two thirds grit and one-third clay in the gravel

$$\text{Then, } \frac{G \text{ plus } X}{100-G} = \frac{2}{1}$$

or $X = (200-3G)$ equals the percentage of sand or shingle to be added to the gravel.

Example:—A gravel was found to contain 58 per cent. of grit. Then the sand or gravel to be added is equal to $200-168=32$ per cent. or nearly one-third of the original volume of sand or grit to be added, heaps could be made of gravel and sand side by side in equal length and height, the width being adjusted to the above proportion and the required quantity of material can be taken from each of the heap and mixed up and put on the road thus entailing no appreciable extra cost.

3. Conversely, where the gravel available at site is seen to contain a higher percentage of gritty material than 66-2/3 per cent. then a certain percentage of clayey material will have to be added on till the proportion of grit to clay is 2 to 1. The percentage of clay to be added will be determined from the formula $X = \frac{3G \quad 200}{2}$ or $X = (1{\cdot}5G-100)$.

Example.—If the gravel is found to contain 80 per cent of gritty material, then the percentage of clay to be mixed will be X=40/2=20 per cent. of the original quantity of gravel.

Where gravel is not available but only grit or shingle, we can use the same mixed with a suitable proportion of ordinary clayey soil, the proportion of clay to be added being worked out on similar lines.

Where, however, good gravel of a ferruginous variety (*i.e.*, red) containing grit and clay in the required proportions, is available within reasonable distances such areas may be acquired for gravel quarries and gravel for the roads obtained from such quarries in preference to gravel at site or to the mixture if the latter proves to be more costly.

4. In Mysore almost everywhere we find gravel along the roads and in the higher regions, the sub-soil is also excellent and hard. It is only occasionally that the lower portions of the valley are soft due to natural high content of the clay in the soil and also the roads being in embankment in such places. In such soft places, even if gravel is used, the surfaces would not be sufficiently strong to stand the heavy motor vehicular traffic. If, in addition, we lay in such places the trackways as indicated in para. 6 of the main paper, we will be able to meet the needs of heavy motor vehicular traffic at possibly the cheapest rate.

5. Mixtures of gravel and sand or shingle as prescribed in paragraph 2 of this appendix to contain finally, grit and clay in the proportion of 2 to 1, would be quite suitable also for blindage on metalled roads.

Diwan Bahadur N. N. Ayyangar: Mr. President and gentlemen. This problem—Roads in rural areas (Village roads)—has been referred to by Capt. Rao Bahadur Choudhry Lal Chand, O.B.E., M.L.A. It is a colossal problem but this has to be tackled. In the usual way of making *pucca* roads, the solution will be impossible. Therefore, we have to find more economical methods and that can be done only by means of gravel roads. But even in places like Mysore where good gravel is available, almost everywhere, it has not been properly investigated or understood. It is therefore that some consideration has been given to get at a correct material and it has been found by experience in certain places that when you put on the gravel available in the site, you get excellent results; in fact far more excellent than even in the case of metalled roads.

Analysing such materials, you find that a material containing twice as much of sandy stuff as the clay content is the best proportion to have. Based on that observation, you find that several of the materials found in so many places are very good. In making this 2: 1 suggestion, as I said, it is necessary to mix various sands available, but mixing is not an easy problem. In order to get at a method generally applicable not only to Mysore but to all India and also outside, this simple process shown to you near Mandya has been evolved. A more or less definite formula has been shown in the appendix*. That factor "two upon one" is for material suitable for roads. The same formula can be used for example in the construction of tank bunds. They must be more retentive of moisture

* On previous page.

and at the same time not given to cracking in the hot-weather. Fifty per cent. sandy material and 50 per cent. of the clayey material can be used. In that case one upon one is the factor in the formula. Similarly whatever else the work may be, you may use similar mixtures by slightly varying the proportions as will be found by experience. So, this is a universal formula, very simple and applicable for various engineering problems that engineers have to deal with. This material being suitably mixed, you can make very good use of this for making *kachha* roads. For example, this morning, there was a discussion about the black cotton soil with reference to mixing of shingle and sand. Supposing you have got to make a six-inch crust. To the 2-inch of the original soil add 4 inches of the sand and gravel and chop it in rainy weather. The whole thing mixes up. Smoothen it and roll it. You have a good gravel road. This is a very simple consideration for dealing with this colossal problem. I may press upon the Engineers to keep that in mind and go ahead with their problems on those lines. You may have made gravel roads, but they may not be suitable for heavily loaded carts like sugarcane carts weighing about two tons and running on 2 inch tyres. For such a traffic, you have simply to lay out two tracks on such a road as in the case of the track road near Mandya. When two carts meet, the ground being fairly hard both of them may be able to pass each other.

One unfortunate thing about roads is that the fundamental and simple engineering axiom, *viz.*, the strength of a chain is the strength of its weakest link, is not kept in view. Below the wheels we want the strongest construction. On other parts of the road there may not be much strain, and yet the strength is made the same. In that way, there is much waste in our road construction. In that portion of the road where the intensity of the load is strongest, the construction too must be strongest. That is the idea with which these tracks have been developed as you saw near Mandya. I think I told Mr. Mitchell once in Bombay, my idea about this question. He said he had tried it in the Punjab and it was not successful. The thing might have been a failure due to the fact that the stone material used there had not been given a suitable binder. So the gravel layer has been sandwiched. Lower down, you have got bigger stones and over it a layer of gravel and above it smaller stones and a layer of gravel and at the top you have got small stones. This gravel works into the interstices of the stone, so that there is no motion and there is no loose metal. When later on motor traffic develops, we need not make the whole road afresh. All that is necessary is to metal the remaining portions and still later on to asphalt or tar it if necessary. So nothing done at present need be undone.

I entirely agree with the criticisms of Rao Bahadur Choudhry Lal Chand and the point of view that he has taken about bullock carts.

I thank you, gentlemen, for your patient hearing.

Chairman: I understand Mr. Hughes will introduce this paper (No. 24) I call upon him to do so.

The following paper was then taken as read:—

Paper No. 24.

OIL AS A BINDER FOR EARTH AND GRAVEL ROADS.

By

T. G. F. Hemsworth, B.A., B.A.I., I.S.E., Executive Engineer, P.W.D., Burma.

Preface.

In this paper the Author endeavours to describe the oil bound road as encountered by him during a 6.000 mile motor tour through the United States of America.

On the journey from San Francisco to Los Angeles he was greatly impressed by the excellence of this type of surface and on his arrival in Los Angeles had the good fortune to obtain an interview with Mr. E. E. East, Chief Engineer of the Automobile Club of Southern California, who, not only provided very valuable information concerning the methods of construction of an oil bound road, but also gave a moving picture demonstration of the actual work.

After leaving Los Angeles the Author had the opportunity of studying the actual methods employed in the construction of many miles of this type of road and on his return to Burma he has satisfied himself that the claims made by the American Road Engineers are substantially correct; he is therefore of the opinion that the oil bound road is a possible solution to the problem of the economic construction of motorable roads in India.

During the early days of motoring, oil was used as a dust palliative and with beneficial results, but experience showed that, while this treatment was effective for a short period, frequent applications of oil were necessary with the result that maintenance costs became exorbitant.

2. With the rapid increase of motor traffic and the absolute necessity of providing more stable foundations, oil as a surface binder was neglected, chiefly due to the fact that its binding qualities had not been clearly recognised. Various methods and materials were employed in an endeavour to produce a satisfactory surface. Bitumen coatings, asphalt carpets, and many types of emulsions were tried but each in turn was found inadequate for the heavier type of motor traffic. Cement concrete was then recognised as the only material which was capable of withstanding the onslaught of modern traffic, and so the main highways of the world are now constructed of this material.

3. With the advent of the world depression, road engineers were confronted with the dire necessity of economy, not only in regard to the construction but also the maintenance of roads; with reduced allotments, their programmes for the construction of concrete roads had to be greatly curtailed and the maintenance of secondary roads proportionally reduced. As in every other branch of the world's affairs mankind has endeavoured to find a substitute; but in the case of cement concrete a substitute has not yet been found, so Road Engineers have turned their attention to the discovery of a material which will be both

suitable and economical for the construction and maintenance of Secondary Road surfaces.

4. In the United States of America this need for economy was probably more keenly felt than in any other country in the world owing to the huge road programmes which had been initiated and to the general demand for better roads. The average American citizen, in his urge to get somewhere, requires and expects good road surfaces and is not content with the loose and dusty gravel which forms the surfacing of a large proportion of the secondary roads in the United States of America. This public demand for better gravel roads incited Road Engineers to turn their attention to this problem, and the ideal at which they were required to aim was a material which when used as a surfacing for a road, would be free from dust during the dry weather, waterproof during the rains, and economical in first and maintenance costs.

5. In Southern California this question was taken up by an Engineer who had previously experimented with oil as a dust preventive. During his experiments he noticed that oil when allowed to penetrate earth and gravel surfaces tended to consolidate these under traffic, and even to remain stable under adverse weather conditions, he also noticed that moisture, if present when the oil was added, appeared to affect the final surface in a very remarkable manner; this interesting fact was further investigated and, as a result of his experiments, the matter was submitted to the Road Chemists for exhaustive examination. After many hundreds of experiments, the results were submitted to the Highway Commissioners, who found that the results of these experiments were gratifying beyond their most sanguine expectations. Stated briefly, the opinion arrived at by the Road Chemists was as follows:—

6. Practically all soils can be successfully treated with oil; gravel or gravelly soils can be more successfully treated than clays or loam soils; and where gravel is concerned its grading has little, if any, effect upon the results. A light oil that could be handled cold in any normal climate is the most satisfactory. The Chemists further declared that if failure occurred in an oil bound road, it would in nearly all cases, be found to be due to faulty drainage and not to traffic or the action of the elements on the surface.

7. The theory of the oil bound surface is merely surface tension which is obtained by causing a film of oil to be formed around each minute particle of which the crust is composed. Although oil and dry materials will, under certain conditions, produce a fairly stable surface, complete stability can only be obtained by means of a "carrier", and, as in the case of bitumen emulsions, water has been found to be the most satisfactory "carrier" because of its affinity for clay and other inorganic matter, it enables films to be formed around each minute particle, and in so doing draws the oil molecules with it. As evaporation takes place the water film gradually decreases until finally the oil is linked directly with the soil or clay particle by means of the oriented surface active molecules in the oil-phase boundary. This oriented structure forms the greatest resistance against water that can be attained with the materials employed. In order therefore to obtain stability it is necessary that each particle of which an oil bound road is composed should be surrounded with a thin film of oil, this film creates an inter-surface tension for each minute particle and it is this inter-surface tension that produces stability. It is therefore essential that the oil present should be sufficient to afford this stability. On the other hand an

excess of oil will permit the particles to float or slide, while insufficient oil will not provide the necessary tension.

8. In a similar manner particular attention must be paid to the amount of water used, an excess of water will cause the oil to rise to the surface of the road and then be carried away by either weather or traffic, while insufficient water will not carry the oil around each micelle or particle and therefore the necessary inter-surface tension will not be obtained.

9. A slight excess of oil will not materially impair the stability of a road, as under traffic the excess oil will rise to the surface and can then be dealt with, but ruts and depressions may be formed and the surface will require to be rebladed and sectioned. On the other hand a surface to which an excess of water has been added will fail in stability because under traffic the water will tend to rise and carry the oil with it thereby destroying the inter-surface tension.

10. It will therefore be realized that a considerable amount of experimenting is necessary in order to arrive at the correct quantities of oil and water required, and as will be understood, the quantities of oil and water will vary with the nature of the materials with which it is proposed to construct the road; but having carried out these experiments, it has been proved by Engineers in America and by the Author by experiments in Burma that it is possible to construct an oil bound road with practically any material provided clay is present in certain proportions.

11. The optimum conditions for the construction of an oil bound road are as follows:—

(1) Good drainage, both surface and foundation.
(2) Dry weather during construction.
(3) Gravel roughly graded from 1 inch to fine sand.
(4) 30 to 40 per cent of clay.
(5) A light low grade oil.

It is not possible to construct a stable oil bound road in swampy ground or on a foundation which becomes unstable due to a rise in the sub-soil water level.

12. Provided conditions are favourable for construction and that traffic is sufficient to consolidate the road before the rains, the surface of an oil bound road will, when consolidated by traffic, become waterproof and will withstand very heavy rain and melting snow. An oil bound gravel road, in proportion to the weight of traffic it is capable of carrying, has been proved to be the most economical type of road yet constructed, with the exception of the cement concrete road, the maintenance costs are also very much less than any other type of road.

13. As regards the carrying capacity and maintenance of an oil bound road, there are several lengths of this in Southern California which were constructed some 5 or 6 years ago. Traffic on these has steadily increased and they are now carrying upwards of 1,000 cars per day. The Road Engineers *estimate that they will carry approximately 2,000 cars* a day. The maintenance cost on these roads during the last 5 years has been negligible compared with those of the previous gravel roads. Not content with the excellent results achieved by the Californian Road Engineers, the Missouri State Highway Department directed their attention to the study of the factors affecting the qualities of the oil

bound road. They realized that any excessive refinements in the construction of this type of surfacing would materially increase the cost and would therefore destroy the advantage which had already been gained through its development. An analysis was therefore made of the different types of road surfaces from the standpoint of surface chemistry and, with this point in view, an attempt was made to apply surface chemical considerations to the successful oiling of earth and gravel roads. It was found that although it was possible to arrive at a fairly complete knowledge of the stability factors in the higher types of Asphaltic pavements, in the case of oiled roads, due to impurities and ununiformity of the components, only general principles could be formulated. Although, in practice, the oiled road had proved to be a success the experiments in the laboratory showed that it was not possible to make it absolutely stable against the influence of the weather.

14. The question was therefore studied from the point of view of the surface-active substances present in an oiled road and of whether those surface-active substances sufficed for the attainment of stability, or the introduction of substances of greater surface activity would improve matters. After considerable investigation it was found that a soap-solution when used in conjunction with oil and water improved the oil bound surface to a remarkable degree. Many hundreds of test samples were made of different kinds of earth ranging from a light sandy loam to a heavy Wabash Gumbo (similar to black cotton soil) with different percentages of oil, soap-solution, and water. These test samples were dried to the same moisture content and tested for tensile strength and disintegration in water. A short summary of the results is as follows:—

Compared with a dry soil and water sample—

(a) the dry soil and oil showed a slight improvement.
(b) the dry soil, oil, and water showed a definite improvement.
(c) the dry soil, oil water and soap-solution showed a very great improvement.

15. When testing for disintegration in water, in some cases an oil treated soil slaked down in less than a day but a sample of the same soil treated with soap-solution and oil resisted the water for a year, and this with as little oil as 3 per cent of the weight of the dry soil and 0·3 per cent of soap.

16. Where the soil contained a relatively low content of organic matter soap showed beneficial results; with a high percentage of organic matter the results with soap-solution became erratic, but an addition of copper sulphate was found to rectify this. Soap-solution in all cases made the mixing of the soil and oil easier and provided a better and more even distribution of the oil throughout the mixture.

17. The conclusions which are therefore drawn from the results of these experiments are that the addition of soap-solution to the materials of an oil bound road will:—

(1) Make the surface more water proof.
(2) Produce a more stable surface.
(3) Reduce the quantity of oil necessary to provide stability and therefore decrease the cost of construction.

A summary of some of the experiments which have been carried out in America and also some rough experimental work by the Author are included in the Appendices to this paper.

18. *Methods of Construction.*—There are three methods employed in constructing an oil bound road:—

(1) Machine pre-mix.

(2) "Mix-in-place".

(3) Hand mixing.

19. *Pre-mix*, as its name implies, is similar to the premix of other road materials which use bitumen as a binder. A central depot is formed, preferably at a gravel pit, where the materials gravel or earth, oil and water are mixed in a power driven mixer, the resulting material is then transported by motor lorries to the road which it is required to surface and dumped on the base which has already been sectioned for efficient drainage, a power blade then spreads, sections, and partly consolidates the oiled material and traffic completes the consolidation.

20. *"Mix-in-place"*.—This method may be divided into two similar operations:—

(*a*) Gravel or earth are collected and deposited on the surface which it is intended to improve, and then oil and water are added to the collected material.

(*b*) An old road surface is scarified and oil and water are added to the scarified material.

21. The latter method being the one more generally employed in America I will endeavour to give a detailed description of the operation. Having first made adequate arrangements for surface and foundation drainage, the following four major operations are involved:

(1) Scarifying and sectioning the road surface.

(2) Applying the oil.

(3) Mixing the oil and scarified material.

(4) Spreading and consolidating the mixed material.

The secret of success lies in the systematic performance of each of these major operations.

22. The first operation consists in scarifying the surface to a pre-determined depth, usually three inches, and to the full width of the "carriage-way" which in America on secondary roads is generally 20 feet, the loose material is then bladed to the required cross section. (A typical cross section is given in appendix I to this paper). Scarifying and sectioning are done with a combined power driven grader and scarifier, the scarifying attachment being carried at the rear of the machine and designed and constructed to operate accurately at any required depth. It is essential that the depth scarified be accurately gauged so that the proper proportions of gravel or earth, oil and water may be obtained.

23. After the first operation has been completed the surface is again scarified and the first applications of oil and water are at once sprayed, each from separate tanks carried on motor lorries: the oil tanks being equipped with pressure spreaders, the amount of oil and water being pre-determined and applied in three applications. Each application of oil and water is followed immediately by harrowing with a disc and sprin tooth harrow drawn by a tractor. The disc and harrow mix the gravel or earth, oil, and water sufficiently to permit vehicles to use the road without the oil adhering to the tyres. This process is repeated until the three applications have been completed.

24. The third operation, mixing the oil, water and material, is carried out in the following manner:—Motor driven graders with their blades set to operate to the depth scarified begin at the extreme edge of the oil treated earth or gravel, and blade the material to the centre of the road, the operation is then reversed and repeated until the material is completely coated with oil, and the entire mixture has attained a uniform colour.

25. The fourth operation, spreading and compacting the mixed material is now put in hand. The material is spread by means of a power blade to a uniform thickness over the width of the "carriage-way", the blade is then operated over the uniformly spread material moving small quantities backwards and forwards, until the true section is obtained and the material is consolidated to a degree when it will withstand traffic without rutting. Traffic then completes the consolidation. A series of photographs to illustrate this operation are appended.

26. The following is a description of the method adopted by the Author in laying a short length of experimental surfacing by hand mixing.

27. A gravel road was selected which was already provided with adequate surface and foundation drainage. Samples of gravel available from the vicinity of this road were carefully tested and the amount of oil and water necessary to produce stability was determined. The existing surface was carefully cleaned of all organic matter, suitable gravel already collected was then spread for a length of 100 feet, 12 feet wide, to a uniform depth of 2 inches. (This method corresponds to the mix-in-place method followed in America except that manual labour was employed instead of machines.) Coolies were then given ordinary watering cans with rose sprinklers, oil in one set of cans and water in another. The coolies were directed to walk up and down the 100 foot length of gravel and sprinkle the contents of their cans uniformly over the whole surface, one oil and one water can working together so that the oil and the water were sprinkled on approximately the same spot at the same time; this operation was continued until the correct quantities of oil and water had been applied.

28. The mixing of the materials was carried out in the following manner:—

Coolies were lined up along one side of the 100 foot strip of road and directed to move, by means of mamooties, the oiled gravel from one side of the road to the other within the 12 foot width, this operation was then reversed and this was found to be sufficient to give a uniform colour and a satisfactory mix. The material was then spread uniformly over the 12 foot width of road and correctly sectioned. Had weather conditions been satisfactory this operation would have completed the work, but unfortunately, the rains being very early, the experiment was carried out under very adverse conditions. Rain had already fallen and the moisture absorbed by the gravel upset the calculations for moisture content, therefore the quantity of extra water had to be decided by the appearance of the material and by roughly testing the surface tension by taking a hand-full of the oiled gravel and squeezing it in the hand, the approximately correct stability being obtained when the material remained compact after hand pressure. In view of the threatening weather conditions it was considered necessary to partly consolidate

the material by rolling with a 2 ton roller and by ramming, this was continued until a stable surface was obtained. Unfortunately within thirty-six hours of this operation there was an abnormal fall of rain before the traffic could complete the consolidation; these adverse conditions continued and the total rainfall up to the 8th August was 166 inches.

29. During the whole of July and up to the first week of August this abnormal rainfall continued and from the 30th July to the 4th August this coincided with the spring tides which backed up the rainwater and caused considerable flooding. The section of road which had been treated with oil was submerged and traffic had to proceed through one foot to eighteen inches of water. When the flood had subsided the road was examined and was found to have suffered very little in consequence; the oil had been washed out of the top layer to a depth of about three-quarters of an inch but the base still contained oil and had retained its stability. Portions of the surface were still compact and waterproof to a remarkable degree. It is therefore reasonable to conclude that had the experiment been carried out under the optimum conditions of dry weather and correct moisture content, the result would have been equal to that obtained by the road engineers in America. It can also be concluded that it is possible to construct a satisfactory and economical oil bound road without expensive machinery but it is suggested that if oil bound roads be constructed on a large scale, motor lorries, carrying oil and water tanks with sprinklers, should be provided.

30. The following is a comparison of costs of the construction and maintenance of different types of road surfaces in Burma, together with some similar types of roads in America:—

Normal construction and average Yearly maintenance costs per mile of 12 foot roadway.

Type.	Construction.		Maintenance.	
	America.	Burma.	America.	Burma.
	Rs.	Rs.	Rs.	Rs.
Cement concrete . .	54,600	38,000	300	200
Bitumen-painted stone metal.	not available.	26,000	†600	1,100
Bitumen emulsion *road tar on stone metal.	,,	22,500	..	1,100
Water bound macadam .	,,	20,000	1,700	2,400
Bitumen-painted laterite .	not known in America.	12,000	..	1,300
Bitumen-painted Delone .	,,	10,500	..	1,300
*Bitumen semi-grout, with 2 inch metal.	not available.	6,500	not available.	not available.
Laterite	,,	6,000	,,	1,400
Delone	,,	5,500	,,	1,200
Gravel	9,000	5,000	1,500	1,100
Oiled gravel, 3 inch coat .	12,300	‡4,530	400	200

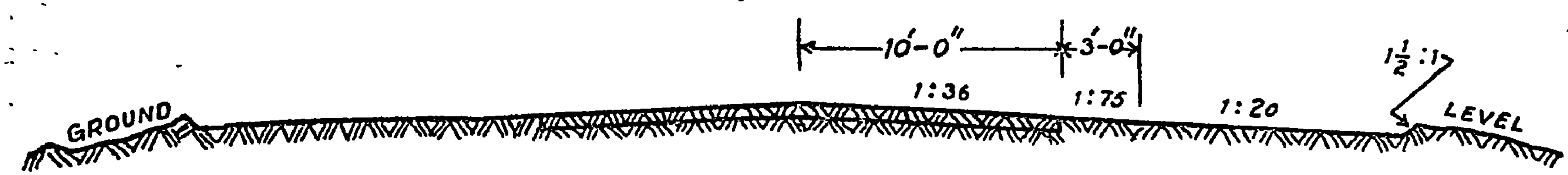
* Over existing macadam surface. Average cost for 3 Districts only.
† Does not include periodical renewal cost.
‡ Cost as per experimental road in Tavoy District, Burma, analysis given in Appendix II.

31. Uses for oil-bound gravel.

1. Road surfaces.
2. Side berms of existing high class road surfaces.
3. Runways for aerodromes.
4. Pathways especially in Jails, Hospitals, Military and Police Barracks.
5. Parade grounds.
6. Floors for godowns, covered passage ways and etc. The oiled material is effective against most kinds of vermin.
7. Tennis courts, and "Browns" for Golf courses.
8. Mud roofs in the dry zones in India, and other parts of the world.

APPENDIX I

TYPICAL CROSS SECTION FOR OIL BOUND GRAVEL ROADS.



APPENDIX II.

Analysis of cost of an Experimental Oil bound Gravel Road in Tavoy, Burma.

Roadway.—12 feet wide by 100 feet long with material 2 inches deep.

Oil used.—Burma Oil Co. earth oil obtained from local bazaar.

Gravel used.—Hill gravel from the vicinity of the road without screening or cleaning.

	Rs.	a.	p.
1. 200 cub. ft. gravel at Rs. 1-10-0 per 100 cub. feet . .	3	4	0
2. Labour for spreading at Re. 0-4-0 per 100 cub. feet .	0	8	0
3. Labour for oiling and watering 100 gals. oil, 150 gals. water; ½ cooly at Re. 0-10-0	0	5	0
4. Labour for mixing, spreading and sectioning; 2 coolies, at Re. 0-10-0 each	1	4	0
5. Labour for rolling and ramming; 5 coolies, at Re. 0-10-0 each	3	2	0
6. 100 gals. B. O. C. earth oil at Re. 0-7-8 per gal. . .	46	14	0
7. Carriage of oil and water	5	0	0
Total .	60	5	0

Cost per mile of oil bound gravel, 2 inch coat . . .	3,332	0	0
,, ,, ,, ,, ,, 3 ,, ,, ...	4,998	0	0

If the traffic be allowed to consolidate the material the cost of rolling and ramming may be deleted; costs will then be as follows:—

	Rs.	a.	p.
Cost per mile of a 2 inch oil bound gravel road	2,990	0	0
say.	3,000	0	0
,, ,, ,, 3 ,, ,, ,, ,, ,, . . .	4,530	0	0
say .	4,500	0	0

APPENDIX III.

Uses of oiled roads in different parts of India.

The efficient administration of any country postulates efficient communications and as the motor car is the vehicle of the future, motorable roads are essential. One is all too familiar with the condition of the types of roads which are impassable or practically impassable for motor traffic during the rains, and dusty and almost impassable during the dry weather.

If we consider two very different Provinces in India we find that:—

Burma has some 3,400 miles of these types of roads.

Owing to financial stringency in Burma, improvement of these types of road will be a slow process, but in Sind a Road Development Programme has been prepared. This Programme provides, during the first 5 years, for the improvement of 2,200 miles of road at a cost of Rs. 77,60,000, and a further 1,000 miles during the succeeding 5 years at a cost of Rs. 20,00,000.

Sind, some 3,000 miles of roads which require to be improved in order that they may carry motor traffic. It is reported that in Sind there are hardly 400 miles of motorable roads in an area of 46,400 square miles and of the remaining roads so many are impassable to wheeled traffic of any sort that 60 per cent of the agricultural produce of the Province has to be carried by camels.

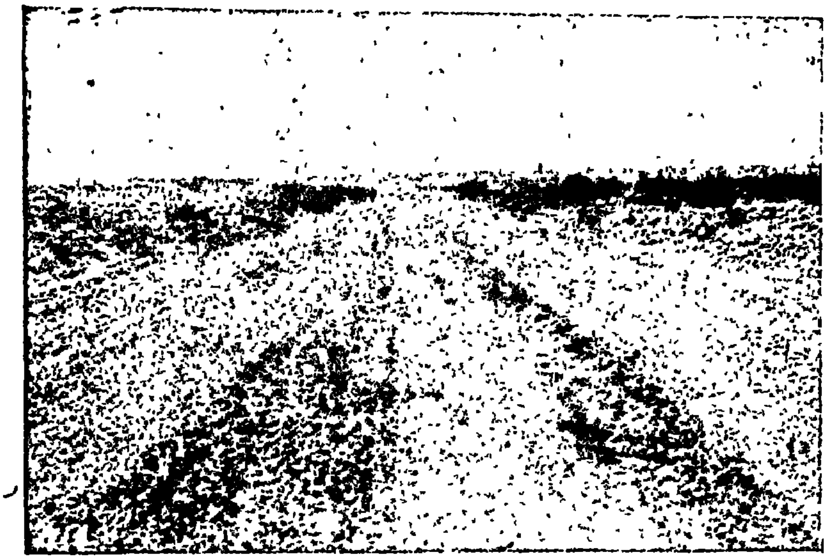
As Sind would appear to be ideal for the construction of oil bound roads, the inclusion in its road Programme of this type of road surface would merit consideration.

APPENDIX IV.

The photographs on pages 216—219 illustrate the "Mix-in-Place" method of constructing an oil bound gravel road as described in paras. 20 to 25 of this paper.

Photograph No. :—

1. Shows the road scarified to a depth of 3 inches.
2. The oil and water is applied to the scarified surface.
3. The disc and spring tooth harrow follows the oil application.
4. The motor driven grader mixes the oiled material.
5. The material is bladed to the centre of the road.
6. The material is bladed towards the edges of the road.
7. The material has now become uniform in colour and small quantities are being bladed backwards and forwards to obtain a uniform and correct section.
8. The operations have been completed and the road opened to traffic.
9. The consolidation by traffic is in progress.
10. The completed road.



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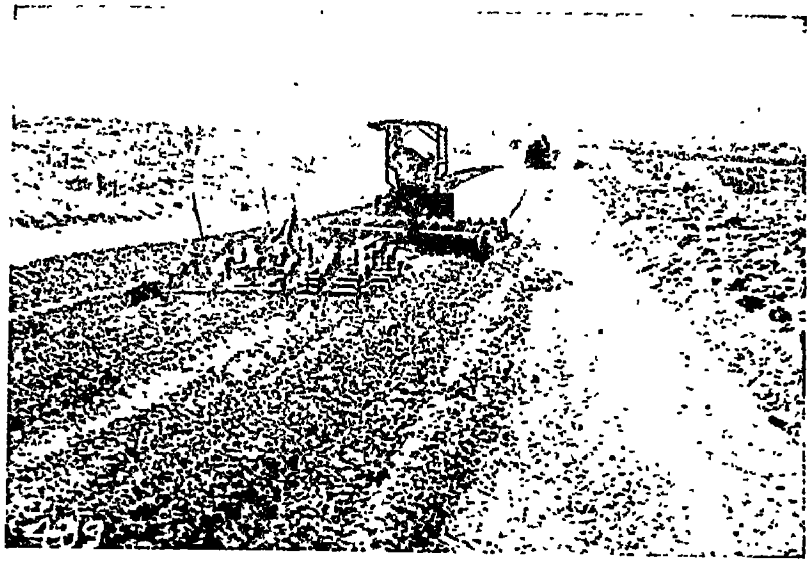

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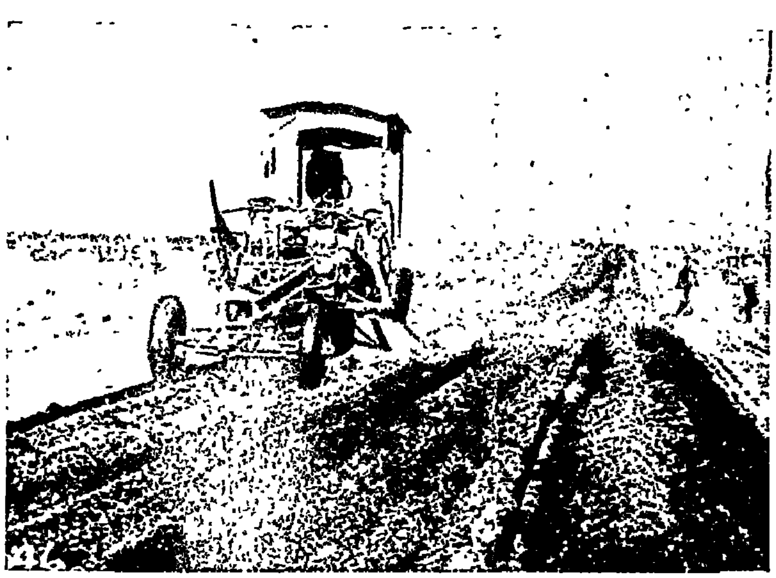

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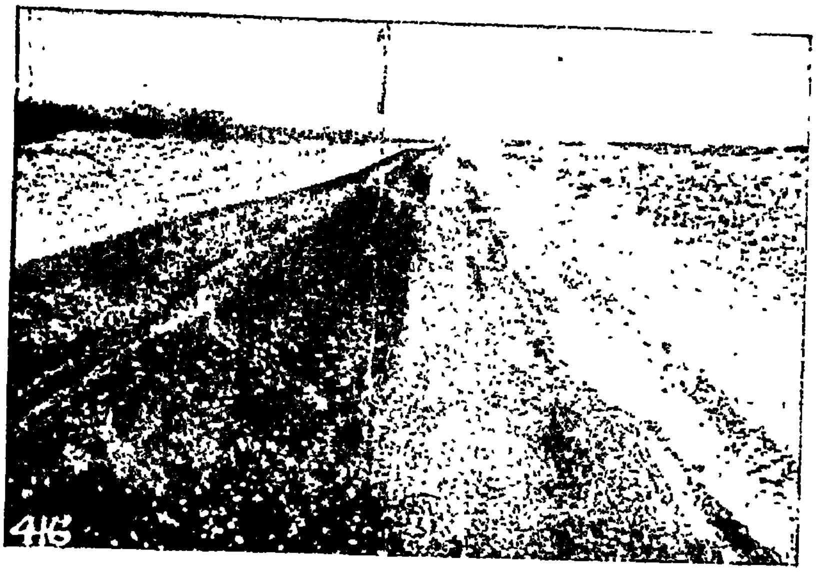

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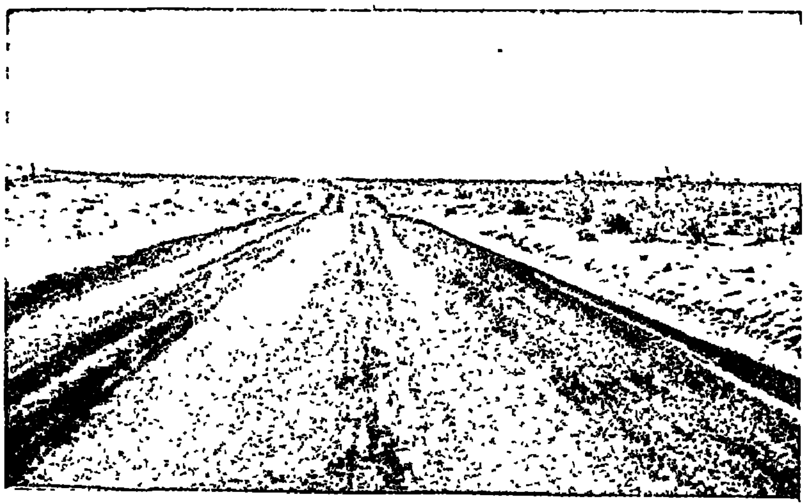

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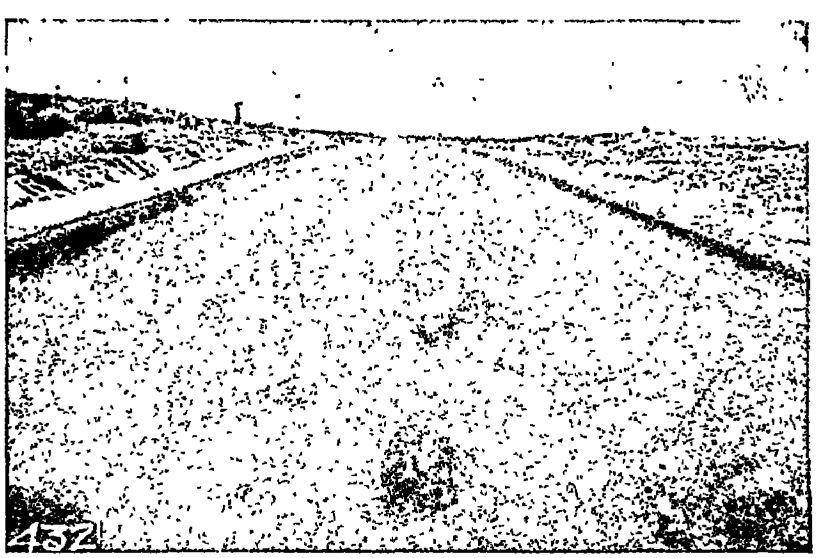

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APPENDIX V.

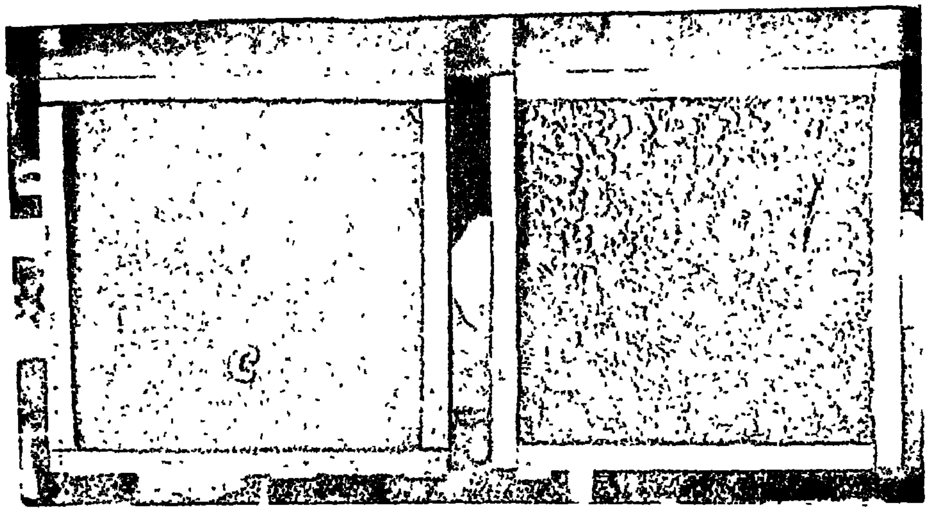
Experiments by the Author in Burma.

The photographs on this page and on the next page represent samples of gravel treated with oil, water and soap solution by the Author in Burma; these samples were made during the dry weather and were then subjected to two months of hot sun followed by three months of very heavy rain, aprox. 100 inches.

2. In the case of specimens, A, B and C, the oil, water and soap solution were thoroughly mixed with the gravel and then consolidated; in specimen D, the gravel was rammed dry, then the oil, water, and soap solution were poured on and allowed to soak in, the mixture was then consolidated.

Specimen.	Percentage of				Remarks.
	Water.	Oil.	Soap solution.	Earth.	
A.	10	5	0·5	20	The sample shows cracks and disintegration but is fairly hard and compact.
B.	10	5	0·5	20	Similar to sample A., disintegration due to large aggregate and too little earth.
C.	10	5	0·5	30	Hard and compact without cracks or disintegration, still retains the polish made by consolidation.
D.	10	5	0·5	20	The weather has washed out all the oil and there is no stability.

The conclusion to be drawn from these results is that this particular gravel requires not less than 30 per cent. of earth or clay, and that the aggregate should not be too large.



3. Many rough experiments were carried out in Burma by the Author using various materials, and different percentages of oil, water, and soap solution. The following is a summary of the more satisfactory results :—

Material.		Percentage of			Result.
		Water.	Soap solution.	Oil.	
Coarse Sand . . .	a.	..	..	5	Not stable.
	b.	10	..	5	Not stable.
Coarse Sand + 20 % earth .	a.	..	..	5	Not stable.
	b.	10	..	5	Fairly stable.
Coarse sand + 40 % earth .	a.	..	..	5	Fairly stable.
	b.	10	..	5	Stable.
Black Cotton Soil . .	a.	..	..	5	Not stable.
	b.	12	..	5	Stable.
Laterite Gravel . . .	a.	..	..	5	Not stable.
	b.	10	..	5	Not stable.
Laterite Gravel + 10 % earth	a.	..	..	5	Fairly stable.
	b.	10	..	5	Stable.
Hill gravel containing 30 % earth.	a.	..	..	5	Fairly stable.
	b.	10	..	5	Stable.
Decomposed rock containing 30 per cent earth.	a.	..	..	5	Fairly stable.
	b.	10	..	5	Stable.
Hill Gravel containing 30 to 40 per cent of earth.	a.	10	0·5	5	Very stable.
				5	

The percentages of oil, water, and soap-solution used are relative to the weight of the material.

In the case of gravel and decomposed rock, the material was screened to 1 inch and under.

In all cases soap-solution improved the stability.

7. Results of Experiments with soil No. 4, with 5 per cent of oil.

Specimen.	Shrinkage in drying.	Behaviour of dried specimen under water.
Moist field soil . .	Very high, breaks in shrinking because of structure.	Disintegrates to large units in 30 min., no further disintegration.
Dry soil + water . .	Very high, but no breaking.	Disintegrates to fine particles in 60 min.
Moist field soil + oil .	High, breaks in shrinking because of structure.	Disintegrates to large units in 60 min., no further disintegration.
Dry soil + oil . .	None	Disintegrates after 15 min.
Dry soil, oil and water .	High, no breaking .	Breaks in 60 min., but no complete disintegration after 10 days.
Dry soil, oil and soap solution.	Medium, no breaking .	Slight breaks after 2 days, slow breaking to large units.
Moist field soil, oil and soap solution.	Medium, some breaking	Breaks in 1 day to large units, no further disintegration.

8. In an endeavour to counteract the detrimental effects of a high percentage of organic matter, further experiments were carried out with soil No. 4. $CaCl_2$ and $CuSO_4$ were added to the samples, the specimens were dried and then submerged in water with the following results :—

Percentage of		Shrinkage.	Result of suspension in water.
$CaCl_2$	$CuSO_4$		
0	0	Medium .	Slight breaks develop after 2 days, slow breaking to large units.
2	0	None .	Slight breaks after 4 days with very slow breaking after 7 days.
2	0·3	None .	No breaks after 40 days submersion in water.

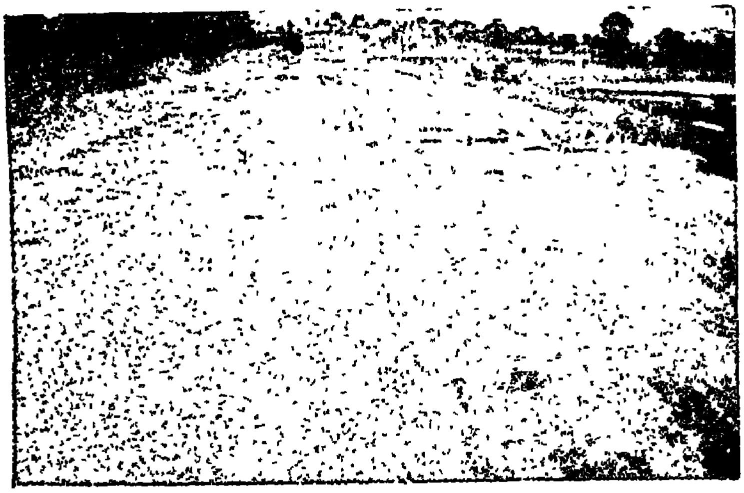
APPENDIX VII.

The Experimental Road in Burma.

Photographs i and ii show the Experimental Section of the oil bound gravel road in Tavoy District after it had been subjected to 4½ days submersion by floods, as described on page 7 of this paper. No repairs of any sort have been carried out.

Photographs iii and iv show the condition of the adjoining untreated gravel road after the same submersion by floods.

Although the Road Engineers in America do not claim that an oil bound road will withstand floods of even the shortest duration, the result of the experiment in Tavoy, Burma would appear to demonstrate that even a 2 inch coat of oil bound gravel is capable of resisting an appreciable amount of flooding



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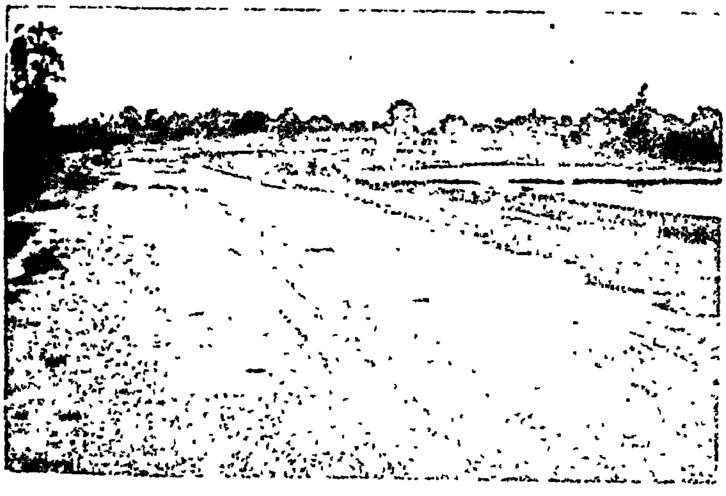

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Mr. Hughes: Mr. President and Gentlemen, Mr. Hemsworth's paper describes a process of earth and gravel stabilisation, which is new to Burma. I am afraid I have nothing to add to what he has stated in his paper. If anybody has any general questions to ask I may be able to answer them, but questions relating to details of the work will have to be referred to Mr. Hemsworth.

DISCUSSION ON PAPERS IN GROUP 5.

Mr. G. B. E. Truscott: One of the previous speakers said that the ryots cannot work for all the 365 days in the year on his fields. There is a saying that "the Lord helps those that help themselves". The Government of Travancore is also out to help those who help themselves. We have in Travancore what is termed Ryots' Road Rules. That is a scheme whereby the ryots cut the roads, *i.e.*, earth roads only and then apply to the Government to take the roads over. There are two ways of looking at the question. One shows that the ryots consider the road is so very necessary that they cut it; another is that we get the land handed over without the considerable formalities of acquisition. The Public Works Department give the ryots quite a lot of assistance in aligning the roads and also advising on other matters. When a road is cut in accordance with the Ryots' Road Rules, the owners apply to Government to take the road over, which Government invariably sanction and also sanction a small maintenance grant which is increased as traffic on the road develops. and when circumstances permit the road is metalled or gravelled and culverts and bridges are also built. Several taluks in Travancore have added to the milage of roads by such means in the past and one taluk in particular has built several miles of roads by this method which have been taken over and improved by Government so that they are really now equal to main roads.

It is really very nice to know that Mr. Mitchell has given funds for building village roads and I promise him that he will hear from me regarding this in the near future.

Regarding paper 23 (b), we have quite a number of gravelled roads in Travancore and here I have to join issue with other speakers with regard to bullock carts. Those speakers spoke of carts doing no more damage to roads than motor vehicles. From what I gather all these remarks have been made with reference to dry weather, *i.e.*, when there is dust on the road. I am not at all concerned as to what happens during dry weather when there is dust on the road; but it is when there is mud on the road with which I am concerned, *i.e.*, during heavy rains when the dust is washed out of the ruts made by the bullock carts and the gravel is badly cut up by thin narrow iron tyred wheels into deep furrows and in the case of a lightly metalled road the metal is displaced and the sub-soil churned up. We have quite a fair milage of main roads which are gravelled and used mainly by motor cars, buses and lorries. There are not many bullock carts on these roads as the towns which they connect are also connected by canals or backwaters on which country craft ply carrying merchandise, etc., which is ordinarily carried on other roads by bullock carts and although the motor traffic on these roads is fairly heavy, the surface is maintained in a good condition both in rains and dry weather at no great

cost. I suppose you know the names of the two large towns of Quilon and Alleppey. The road connecting these two is gravelled and the maintenance grant is Rs. 500 per mile per annum and the surface is so good that one can travel by motor comfortably at 40 to 50 miles an hour; but judging by similar roads not carrying such heavy traffic, but carrying bullock carts I doubt if one could even travel at 20 miles an hour if there was a preponderance of bullock carts on these roads as you generally have on other roads in India.

Mr. Syed Arifuddin: Mr. Chairman and Gentlemen, I wish to speak of my experience with regard to gravel roads. In Hyderabad there were not so many metalled roads about 15 years ago as we have now. Mostly they were gravel roads. Cart traffic used to play havoc with them whenever it exceeded a certain limit. I found by experiment that the best gravel roads could be made when the percentage of clay is below 20, the less the better. Some of the soils which we in Hyderabad call rocky mooram contains clay as low as 7 per cent., and yet all stone particles are surrounded by a thin layer of clay. It is this layer of clay which combines the whole material after consolidation and the pieces of stone keep the road well drained. When the Nizamsagar was being constructed I was in charge of construction of a portion of the canal. At that time a road was temporarily taken through the canal bank. The bank consisted of pure black soil about 12 feet deep. The gravel used for the road contained about 35 per cent. of clay, but the road could not stand the traffic during a single monsoon. I found the remedy in using another gravel which contained 10 per cent. of clay. The road behaved very well during 2 subsequent monsoons, after which the traffic was diverted on the new road. The same result could not be expected from a mixture of sand and clay.

Rao Bahadur Choudhry Lal Chand has appealed to the engineers to pay attention to the village roads. There is hardly any engineer present here who is not desirous of doing a good deal towards village uplift in the form of housing schemes or construction of village roads, etc. About 7 or 8 years ago, I had some work to do with the development of a very backward district called Adilabad. The Chief Engineer was very keen on improving village communications. He asked me to draw up a scheme for this object. I made out a rough scheme of improving village communications of about 1,000 miles in length in one year. I found then that I could do so at a cost of about Rs. 200 to Rs. 300 per mile. This consisted of clearing a surface 20 feet wide of the shrubs and levelling the ground wherever it was necessary, improving approaches to nalas and streams, and putting some gravel where the soil was bad. For some reasons the Government had to close down the development work after constructing some very fine roads in that district and therefore the idea of village roads had to be dropped.

In connection with the Nizamsagar project I constructed nearly 200 miles of service roads about 9 years ago at a cost of approximately Rs. 250 per mile. Some of the miles cost only Rs. 100 where the soil was good mooram. These are being maintained and are still serviceable. Lately in connection with the development of the Nizamsagar project His Exalted Highness the Nizam's Government have made a good beginning in this direction by connecting a good many villages by cheap gravel roads. The

money was paid from local fund. I lately submitted a scheme costing about 15 lakhs (I do not remember at present the exact amount) for a number of roads in the Nizamsagar area where there is already a fair milage of roads existing. The scheme will facilitate the village traffic very considerably by bringing over 200 villages close to the roads. The work of connecting villages by tolerably good cart tracks and maintaining them however economically we may do it, will require enormous amount. This is really a part of village uplift work and it deserves to be given nearly the same importance as housing scheme for the villages, drinking wells and sanitation. I doubt whether any Government in India can, at present, afford to meet the required expenses based on any reasonable programme from their resources. The Government of India has very kindly made a good beginning by allotting last year a sum of a crore of rupees for village uplift work. But this is too small a sum to make any appreciable impression in a reasonable period of time on the outlook of village life considering the immensity of the area and the population, it is meant to benefit. If it be desired to go ahead fast in this direction, all the Governments in India may have to reserve a portion of their income for village uplift work and further augment their income by new taxation specially for this purpose alone. For instance, if instead of one anna in a rupee the local fund cess is increased to 2 annas and one anna is reserved for village roads a good deal of work can be done. Suppose that the income of a State or a province from land alone is 3·2 crores, local fund revenue at one anna in a rupee will be 20 lakhs. If this money be reserved for village roads we can do several thousand miles of village tracks every year. We might thus be able to finish the whole programme in a period of 10 to 20 years and afterwards probably half of the above sum may be sufficient to maintain it.

If the Governments place money at the disposal of their engineers, Rao Bahadur Sahib may rest assured that the engineers will be simply too glad not only to build village roads as economically as possible but will give every help they can in every kind of village uplift work. What is necessary for us at his stage is to conduct experiments on every kind of soil and determine the cost of constructing various kinds of cheap roads and cart-tracks to suit the local traffic. From the result of these experiments it would be possible for the Governments and local bodies to choose the kind of roads. In order that the engineers may carry out their experiments it is very essential that the various local bodies and Governments should place a certain sum annually at the disposal of the engineers concerned.

Mr. C. D. N. Meares: Mr. Chairman and Gentlemen, I wish to make some observations with regard to paper No. 24, but hasten to reassure Mr. Hughes that I do not intend criticising it! Paper No. 18 has evoked considerable discussion on the merits and disadvantages of separate roadways for cars and bullock-carts. The suggestions put forward made no definite mention of the point but the discussion certainly was directed towards turning bullock-carts off the existing road. Now in Paper No. 24, you see at the beginning that Mr. Hemsworth feels that American road Engineers' claims regarding oiled roads are substantially correct. He has, therefore, suggested to me a possible method of tackling the question of economic construction of *motor* roads in India. If that is feasible, it may

be worth-while considering the possibility of leaving bullock-carts on the centre of the road and allow motors to use the road alongside. In many cases, you have got roads of forty feet width, so that such an experiment ought not to present much difficulty. If you can leave some suitable width in the centre in a fit condition for bullock-carts, I see no reason why we should not adopt some method of gravel construction on the berms, as suggested by Mr. Hemsworth, for motor cars—a reversal of the usual procedure. I make this suggestion for your consideration.

Rao Bahadur Choudhry Lal Chand: Mr. President, and Gentlemen, I am glad the question of village roads has received nearly general approval and I am sure something will be done by this august body of Engineers before the year is out.

There is one thing which I have to answer. Mr. Truscott from Travancore, seems to have misunderstood me. When I said that the peasant or the farmer does not get work for all the three hundred and sixty-five days in the year, my point was that for him it is economical to use his own cart for conveying his produce to the market. He has got enough time for that and he cannot pay the middle man for carting his produce and so he must use his own bullock-cart.

Mr. Truscott made very nice suggestion saying that in Travancore the ryots help themselves and make their own roads in their spare hours. May I ask him how he will feel if this principle was applied to motor-car owners also and how many motor-car owners will make their own roads themselves? He may kindly understand that the 'begar' system has been abolished everywhere except perhaps in Travancore State which I hear is a very forward State. There is a road tax everywhere. There is Land Revenue and people pay their own taxes. They are already overburdened and my question was simply that of definite distribution of the funds that you are devoting to road-building. I only ask you to give the poor man of the village his proper share of these road funds; not only the particular road fund that is at the disposal of the Consulting Engineer but the road fund in every Province or State. The poor man living in the village must have his share. He should not be sacrificed for the rich. Probably, Travancore is acting on the principle that

> "To him that hath shall be given
> From him that hath not, shall be taken away"

—even the little which he has. He said that bullock-carts do damage to gravel roads. But gravel roads have been in existence for a long time past and bullock-carts also have existed. During the time motor-cars were not here, this question was not raised. This question has been raised only after motor-cars have come in. Why should those bullock carts be ousted from these roads? These roads were meant for those bullock-carts! If you want good roads, certainly do ask Government to make them for you, but at the same time, make a suggestion that petrol tax should be increased and that rich people should be taxed. Why should poor people be sacrificed for the convenience of the rich? From the administrative point of view. I suggest that only *katcha* roads are needed and these amenities are not needed for the administration. The administration will

not suffer if they do not exist. These amenities are meant only for the rich. Motor-car owners have so much voice in the administration that they cater for themselves and not for these poor people. Bullock-carts are a necessity in India. India is a poor country. Of course, I shall be pleased, when conditions become such that every villager and every farmer becomes a car-owner, becomes so rich that he is enabled to purchase a car. I would like to see those conditions. But till then, he must be allowed to use these roads which he has been using for ages. Why should *you* oust *him?* You had better make a proper road of your own. Have a separate tax for them. You do not want to pay taxes. When the petrol tax is raised, everybody raises his voice against it because it taxes the rich. The poor man wants to keep his cart to himself.

Mr. Syed Arifuddin, on the other hand, has given a description of village roads on which he spends precious little, but we, villagers are satisfied with even small mercies. He has described that he wanted to make a road of one thousand miles length, but he had to give it up. Let us hope that his intentions may some day assume practical shape and thus the poor people will have that road made for them.

I have to bring one more fact to your notice. I would not have come before you on this subject and with this grievance, if you had not assumed a cosmopolitan name, that is, "Roads Congress". Call yourself "Metalled Roads Congress". I will not come to you. Call yourself "Motor-car Roads Congress", I would not come to you. But since you assume a cosmopolitan name and do not cater for the millions of people that await your kind attention, I have had to come to you. I should not be misunderstood for these statements. My suggestions are in the nature of requests to a body of experts who are responsible for the making of roads. It lies in your hands and I have only drawn your attention to the fact that you can only deserve to be called a "Roads Congress" only if you cater for the ryot also. Otherwise, your name will have to be changed. At any rate, if you do not do it, others will do it for you. That is all that I have to say.

Chairman: Gentlemen, we have finished the discussion of papers under Group Five. I have nothing to add to what has been said by various speakers. I am in general agreement with the views of Capt. Rao Bahadur Choudhry Lal Chand. The only point of difference is as regards ways and means. To my mind, there appears to be some confusion in his paper as between the Road Development Fund and the Provincial Revenues Fund with which this Congress has nothing to do. The Road Development Fund is built up mainly out of petrol tax and that tax is recovered mainly from users of motor-cars. The question of village uplift and of village road construction is the concern mainly of Provincial Revenues. The Government of India no doubt agree that the Road Development Fund can be and should be expended on the construction of feeder-roads. But as regards construction of village roads in the interior, I think it is a very large question and so far as the road development fund is concerned, we cannot say that the entire proceeds should be spent on their Construction, as their author seems to suggest.

This is all, I have to say.

CORRESPONDENCE.

1. Comments by the author, Mr. T. G. F. Hemsworth, on points raised by Mr. C. D. N. Meares, during the discussion on Paper No. 24.

I welcome the suggestion of Mr. Meares that experimental oil bound gravel roads should be constructed on the berms of existing roads, but in view of the excellent results obtained in America with this type of surface for motor traffic, I suggest that extensive further experiments with motor traffic are not necessary.

The consensus of opinion appears to be that the solution to the road problem in India entirely depends on the provision of a low cost road surface which will withstand the destructive action of bullock-carts. Apart from the fact that the cost of a cement concrete road is prohibitive as compared with the cost of other types of road surface, experience has shown that not even cement concrete will withstand the abrasive action of intensive bullock cart traffic.

This problem might be viewed from another angle. If an economical type of surfacing can be produced which is capable of carrying motor traffic and bullock-cart traffic with a certain amount of rutting but is of such a nature that it can be repaired both rapidly and economically, some progress might be considered to have been made towards the solution of this problem.

With this idea in mind I would prefer to test the oil bound gravel road against motor and bullock-cart traffic, and in order to arrive at an economic traffic intensity a careful traffic census should be maintained.

Compared with other types of road surface which are capable of carrying a similar intensity of motor traffic, the oil-bound gravel road is both economical in construction and in maintenance costs and is capable of being repaired very rapidly. If the surface becomes rutted or uneven all that is required is to scarify the damaged portion and allow the traffic to re-consolidate.

As Tavoy District Burma, where the experimental lengths of oil bound gravel have been laid, possesses few bullock-carts I was unable to test this type of road surface against intensive bullock cart traffic, but I found that any ruts or wheel marks on this surface were subsequently "ironed out" by motor traffic and, in America, where the surface of an oil bound gravel road had been cut up by heavy farm tractors repairs were carried out by merely running a blader over the surface.

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2. Comments made by the author on the remarks of Mr. Syed Arifuddin on Paper No. 23 (b).

Mr. Syed Arifuddin states that in his experience the best gravel roads have a clay content of less than 20 per cent. and suggests that it is possible to construct a satisfactory gravel road with a clay content as low as 7 per cent.

Might I suggest that the satisfactory results obtained with the low clay content figures may be due to the moisture content. Roads constructed in the vicinity of canals presumably are subject to moisture and, provided the materials (gravel and sand) are correctly graded, the more moisture there is present the less clay required to produce stability.

Nature's most remarkable example of this type of stability is a sandy sea-shore shortly after the tide water has receded, perfectly graded sand combined with the inter-surface tension of the sea-water produces sufficient stability to carry a racing motor car at a speed of nearly 300 miles per hour. If the correct moisture content can be retained in any perfectly graded material or combination of perfectly graded materials stability will be obtained.

In regard to the construction and maintenance of roads in black cotton soil areas, the result of experience gained in Burma coincides with the results obtained by Diwan Bahadur N. N. Ayyangar, but I suggest that more adequate drainage than that shown in the Cross-Sections on page 200 of his paper No. 23 (b) is necessary; poor drainage will raise the moisture content of the materials in the road formation and may possibly destroy the stability.

Second Day, Friday, January 10, 1936 (contd.).

GROUP 7—ROAD TRAFFIC (PAPER No. 29).

CHAIRMAN:—MR. H. E. ORMEROD.

Chairman: Gentlemen, I will ask Mr. H. Rangachar to introduce his paper on the regulation and control of motor transport in Mysore.

The following paper was then taken as read:—

Paper No. 29.

REGULATION AND CONTROL OF MOTOR TRANSPORT IN MYSORE.

By H. Rangachar, M.A., Divisional Superintendent, Mysore Railways.

I.—Introductory.

The Mysore Motor Transport Committee and the passing of the Road Traffic and Taxes Regulation.—In October 1932, the Government of Mysore appointed a Committee called the "Mysore Motor Transport Committee", with very wide terms of reference, to enquire fully into the question of motor transport in the State in all its aspects and submit their recommendations for the regulation, control and taxation of motor traffic. On the Committee, which consisted of both officials and non-officials, were members representatives of the important interests connected with the transport in the State in general and the motor transport in particular. The Committee consisted of the Inspector-General of Police, the Chief Engineer, Public Works Department, a District Magistrate, the Traffic Manager of the Mysore Railways, two important operators of motor bus services in the State, the President of a District Board and the President of the Municipal Council of Bangalore, who holds an important place in the industrial and commercial activities of the State. The Committee was very fortunate in having as its Chairman Sir Charles Todhunter, the President of the Indian Taxation Enquiry Committee, a distinguished administrator and statesman who had made a very detailed study of this subject and of the transport requirements of the State. The Committee submitted a unanimous report in April 1933 and the Government, after a full consideration, accepted almost all their recommendations and introduced the necessary Bill in the Legislative Council in December 1934. The Bill having been passed by the Legislative Council in its last Sessions and having received the Royal assent, was promulgated into law last July. This new Act, called "The Road Traffic and Taxes Regulation" is to come into force from the 1st of January 1936. The system of regulation and control of motor transport that is thus to come into force has some distinctive features of its own and is, in some important respects, so different from the system generally obtaining in other parts of India, that a brief description of it may not be without some interest and value to the members of the Roads Congress.

2. *Objects of the Road Traffic and Taxes Regulation.*—Prior to the passing of this Regulation, the law governing the motor vehicle traffic in Mysore was the Mysore Motor Vehicles Regulation, the same as the Indian

Motor Vehicles Act. This did not confer the powers necessary for enforcing the new system and hence the new Regulation, supplementary to the former, had to be passed. The objects of this new Regulation are to provide—

(i) for a more efficient system of licensing and control of public service motor vehicles carrying passengers with a view to placing this transport on a sound economic basis by eliminating *unnecessary and wasteful competition*,

(ii) to secure the co-ordination of the public service motor transport with railways with the object of obtaining the best and most economical public service,

(iii) to provide for the better regulation and control of motor goods vehicles,

(iv) to introduce a system of taxation equitable in its incidences on the motor traffic and on different classes of motor vehicles, and

(v) to set up a suitable machinery for working of the motor Laws and the rules under them

II.—The Traffic Board.

3. *The existing system of control of motor transport in Mysore and British India.*—The last item, *viz.*, the machinery to be set up by the Regulation will be examined first, as it is one of the most important provisions of the new Regulation. Prior to this Regulation, there was not in Mysore any one central authority for the regulation and control of motor traffic. The rules in connection with motor traffic were enforced by the police, as part of their general duties, the licensing and control of public service motor traffic was exercised by the District Magistrates in their respective jurisdictions. This system, especially in regard to the control of public service passenger vehicles, is analogous to that obtaining in most of the provinces of British India.

4. *Its drawbacks.*—This system has many drawbacks. In the first place, there is no central authority responsible for the administration of motor traffic. This administration vests in a large number of different local authorities and there is no body or organisation, apart from the Government itself to view the needs of this traffic as a whole and enforce policies and measures common to the whole province or the State. It is hardly possible for a Government to devote the time required to regulate the day to day administration of the motor transport with its innumerable small details. The result is that the necessary control is exercised by authorities who view the question from the limited outlook of a District. This system of District administration or administration by local bodies which was sufficient for older means of transport with their very limited range is obviously unsuited to fast traffic like that of motors which knows no limitation of Province or States.

Secondly, there is no machinery under the system to ensure a proper co-ordination within the sphere of the motor transport itself and still more with other alternative forms of transport, particularly the railways. Transport is a public utility service and public interests should be the main criterion by which it should be regulated. It is obvious that unnecessary and wasteful competition is harmful and that public interests are

best served by utilising the several means of transport in the spheres in which they could render the most efficient and economic service. This cannot be achieved under the present system of multiplicity of authorities enforcing policies from the point of view of local requirements without a co-ordinating central authority.

5. *The development of motor transport in India.*—There is also one other point in this connection to which attention may be drawn. Amongst the several inherent special advantages of motor transport, must be mentioned the fact that this requires comparatively little capital outlay, that the capital invested in it is not fixed to any particular route and wasted if that proves unremunerative and that, being operated in units of single vehicles, it can be worked most economically even in regions of very light traffic, as the provision of transport facilities can be graduated approximately to the volume of traffic offering. In view of these advantages, motor traffic is specially suited to a country like India, with its vast distances and with traffic too light for a Railway in most of these places. Motor transport is at present the only means which can provide fast transport at the cheapest cost in these areas. Despite this, the motor transport has not made any appreciable progress in this country. Though India is the second largest country in the world in population and the seventh largest in area, her resources in the matter of motor vehicles are very poor. Of the total number of 33,351,214 motor vehicles in the World as at December 1933, the United States of America had 23,819,537 or 71·4 per cent., the British Empire, 4,040,874 or 12·1 per cent., while British India had 172,988 vehicles or ·0005 per cent. of the motor vehicles of the world *[1]. The figures showing the motor vehicles on the basis of population are no less significant; there is one motor vehicle per 57 of population in the world as a whole *[2], 1 per 4·9 in the United States of America, 1 per 9·1 in Canada, 1 per 34 in Great Britain, 1 per 117 in Germany, 1 per 215 in Italy *[3], against the corresponding figure of one vehicle per 1883 of British India *[4]. In Great Britain, the total vehicle miles of public service passenger motor vehicles were in 1933 1,309,800,000 and the receipts from them amounted to £58,200,000 in round figures *[5]. It has been estimated that in the United States of America, motor buses did in 1931 the same passenger mileage as Railways, *viz.*, amount 25 billion passenger miles, while the ton-milage was 325 billions by Railways and 25 billions by motor trucks *[6]. The private automobiles are estimated to have covered 400 billion passenger miles. Corresponding statistics for India are not available. The total number of miles covered by motor buses in Mysore averaged to 13,120,000 miles during the year ending with 30th June 1934. The figures given above are sufficient to show how poor India is in the matter of motor transport resources and that, in spite of the country being most suited for the development of motor traffic. This poverty is due to many causes amongst which must be mentioned the backward economic position of the country, the dearth of sufficient roads, the absence of a balanced and properly planned road system, etc.; there

* [1] The Motor Industry of Great Britain.
* [2] Road and Rail in forty countries.
* [3] Final Report of the Royal Commission on Transport (Great Britain).
* [4] Road and Rail in forty countries.
* [5] Report of Traffic Commissioner.
* [6] Report of the National Transport Committee of U. S. A.

is however no doubt that the pace of development would have been accelerated if the public service motor transport was a paying industry; that it is not so is due to several causes, one of the chief being the absence of a central authority in each province charged with the duty of making and enforcing regulations, avoiding unhealthy and wasteful competition and fostering generally the development of this traffic in co-ordination with others. There has been a remarkable progress in this direction during the last two years; the report of Messrs. Mitchell & Kirkness and the Road-Rail Conference held in Simla in 1933 have led to the establishment of Boards in some provinces and of the Central Transport Advisory Council for India. Though much valuable spade-work has been done, the field to be covered is still very large.

6. The new Regulation establishes a Traffic Board for Mysore. This Board is, subject to the direction of the Government, the central authority in all matters connected with the administration of roads and of road traffic. The principle on which the Board has been constituted is that the regulation and control of transport should be in the hands of a body representative of those providing transport and of those directly served by such transport agencies.

7. The Todhunter Committee, in their report, observed as follows in regard to the qualifications which they considered essential for members of the Board in Mysore:—

> "What is wanted in the first place is men with a knowledge of the whole State and sufficient vision to be able to examine a project from the point of view of its advantages to the State as a whole and its appropriateness with reference to the whole network of roads and railways in Mysore and in the neighbouring Provinces, without being diverted by special considerations of the advantages of particular areas or particular modes of transport. In the next place, they will require a knowledge of traffic questions and of the trade and industries of the State sufficient to enable them to appreciate the desirability of developing transport in particular areas. In the third place, they will need a knowledge of modern transport and modern road developments in different parts of the World, and lastly, they will require a knowledge of the motor laws and of the means of regulating this traffic which is becoming increasingly difficult all over the World".

8. The composition of the Board as finally decided by the Government is as follows:—

I. Ex-officio Members.

(1) One of the Members of Council (Chairman).

(2) The Inspector-General of Police.

(3) The Agent, Mysore Railways.

(4) The Chief Engineer of Mysore.

(5) The Director of Industries and Commerce.

(6) The Secretary to the Board.

II. Non-official Members.

(1) One representative of the Local Authorities in the State (to be nominated by Government).

(2) One representative of owners of private motor vehicles (to be nominated by Government).

(3) One representative of agricultural interests (to be nominated by Government).

(4) One representative of proprietors of public service motor vehicles (to be elected).

NOTE.—Pending the formation of an electorate, the member representing this interest will in the first instance be nominated by Government.

(5) One representative of trade and commerce in Mysore (to be elected).

9. It was the intention of the Government to allow the public service motor vehicle operators to elect a member to the Board in order to give this most important branch a direct hand in the administration of its affairs. As well-organised public service vehicle owners' associations representative of the operators of all districts were not in existence, the Government decided to nominate the representative in the first instance, pending the formation of a suitable electorate. With the formation of suitable Associations, this interest will be given the right of returning a member to the Board by election. The Chamber of Commerce, Mysore, has been given the franchise to elect the member representative of the interests of Commerce. This Board thus constituted is in the nature of a Round Table Conference of all interests directly connected with transport, with due representation for each and no undue weightage for any. Adopting the words of Mr. Herbert Morrison, the Minister of Transport of the Labour Government to whose initiative the London Passenger Transport Act owed its origin, a Board like this may be relied upon to bring to bear on its duties not "a tube mind or an omnibus mind" but "a transport mind".

10. A criticism that may be made against the composition of the Board in Mysore is that, its membership is rather large and that such a body cannot be expected to take urgent executive action. While there is some force in this criticism, it should not be forgotten that the Board could not be made smaller without omitting representatives of interests whom it was very necessary to include. Secondly, the Board's main function will be to fix the general lines of policy and co-ordination, the execution of the policy being left in the hands of the executive staff under the Board and in districts. In view of this, the large membership does not seem to detract from the usefulness of the Board. There is no organisation similar to this Board in any Province in British India except in the United Provinces, where a Board of Communications is, it is understood, about to be set up.

11. The fact is now generally recognised that the best way of dealing with motor traffic is to make the regulations sufficiently flexible and leave their administration in the hands of an important central body or Board. Boards of different kinds are therefore becoming common. Such Boards exist in Australia, South Africa and in some countries on the European Continent. A most conspicuous example of such a Board is the London

Passenger Transport Board set up under the London Passenger Transport Act of 1933. This Board consists of a Chairman and 6 other members appointed by some specified independent bodies called "Appointing Trustees". To this Board is entrusted the working and management of all passenger transport undertakings in the "London Transport Area" excluding the working of the 4 main-line railways.

The latest instance of such a Board in the British Empire is the Northern Ireland Transport Board, set up under the provisions of the Road and Railway Transport Act of 1935. This Board is to take over the administration of all transport services, goods and passenger (and not only passenger transport as in the case of the London Passenger Transport Board) in Northern Ireland with the exception of those of the Belfast Corporation.

The Boards thus constituted in different countries vary from those which are purely advisory or deliberative to those entrusted with full powers and responsibilities for all transport in any fixed area or country. The Board in Mysore occupies an intermediate position and has effective powers of regulation and control sufficient to enforce common policies in motor transport and secure co-ordination with other forms of transport.

12. *District Traffic Advisory Committees.*—A Central Board for a whole Province may not have sufficient acquaintance with local requirements and needs of each district. To remedy this, the Mysore Act provides for the appointment of District Traffic Advisory Committees in each district with the District Magistrate as Chairman and persons, representative of different interests connected with the transport in the area as members. The functions of the District Traffic Advisory Committee are, as its name implies, mostly advisory and are to represent to the Board the Traffic requirements of each district.

13. *The functions and duties of the Traffic Board.*—The functions and duties of the Traffic Board in Mysore are as follows:—

(a) To administer the motor laws of the State and the rules made thereunder,

(b) to regulate and control the public service motor traffic in co-ordination with other forms of transport in the State,

(c) to watch the collection of taxes on motor vehicles, and

(d) to administer the Road Fund, into which all the taxes on the motor traffic are credited.

According to Section 5 of the Regulation, "it shall be the general duty of the Board so to exercise its powers as to secure the provision of an adequate and properly co-ordinated system of public service motor transport and for that purpose, while avoiding the provision of unnecessary and wasteful competitive services, to take from time to time such steps as it considers necessary for extending and improving the facilities for such transport in such manner as to provide most efficiently and conveniently for the needs thereof".

With this end in view it is the duty of the Board to control the number and distribution of public service motor vehicles. It is to determine from time to time the number of licenses and permits to be granted for each,

route and for this purpose is to be guided by the following considerations, *viz.*,—

(*a*) the suitability and capacity of the road or roads or portions thereof covered by every proposed route for the carriage of public service motor vehicles;

(*b*) the extent, if any, to which the needs of the proposed routes or any of them are already adequately served;

(*c*) the extent to which the proposed service is necessary or desirable in the public interest;

(*d*) the needs of the area as a whole in relation to traffic (including the provision of adequate, suitable and efficient services, the elimination of unnecessary and unremunerative services); and

(*e*) the co-ordination of all forms of transport including transport by rail.

In accordance with the above provision rules framed under the Regulation provide for the Traffic Board:—

(*a*) to fix the number of bus services for which permits may be issued on all routes,

(*b*) to lay down qualification of permit holders,

(*c*) to select the operator of bus services on through main routes common to two or more districts or common to the State and neighbouring Provinces, leaving the selection of permit holders in local routes to the district authorities, and

(*d*) to fix the fees to be charged on each route within the maxima and minima prescribed by the Government.

The Regulation also gives powers to the Board to hold enquiries into accidents in which motor vehicles are involved.

This part of the Regulation entrusts the Board with sufficient powers to exercise adequate and effective control over public service passenger motor transport, to improve the conditions of this transport by eliminating the evils of excessive number and uneven distribution of services on roads with the consequent unhealthy and destructive competition and to secure the necessary co-ordination with the Regulation in public interests.

14. *Control of motor goods traffic.*—Public service motor goods traffic is, in some essentials, so different from passenger transport that the system of control suited to the latter cannot be applied to the former.

> "The transport of goods by road does not lend itself to a licensing system such as is practicable with passenger transport by road. The passenger vehicles are bound to certain routes on which they run to fixed time-tables, while this is not the case with goods vehicles which ply on different roads according to the custom they get. The haulier can have no fixed rates or time-tables as the essence of his trade is to carry anything from anywhere to anywhere. The haulier's lorry is thus "analogous to a tramp steamer" while the passenger buses can be compared to regular liners".[1]

A different system of control has to be adopted in the case of these.

[1] Report of Royal Commission on Transport.

15. In this matter the Mysore Regulation adopts the principle underlying the English Road and Rail Traffic Act of 1933, *viz.*, that no person shall use a motor goods vehicle on a road without a carrier's permit. This permit is to prescribe the area in which the lorries are to be worked and the conditions subject to which they can work. Such conditions may, subject to the rules prescribed by the Government from time to time, include the following:—

(*a*) A condition that the motor lorry shall be used only in a specified area or between specified places;

(*b*) a condition that certain classes or descriptions of goods only shall be so carried;

(*c*) a condition that goods shall be carried only for specified persons;

(*d*) a condition that the motor lorry shall not carry more than the specified number of persons;

(*e*) when the vehicle is a motor lorry intended to be let or plied for hire or reward, such other conditions as the prescribed authority may think fit to impose in the public interest and with a view to prevent uneconomic competition.

16. The object of this part of the Regulation is to improve condition of the motor goods transport, by eliminating some of the evils at present. In the first place, private motor lorries, on which taxes were lower than on lorries for hire, often used to carry goods for hire and at very uneconomic rates, thus placing public service lorry owners at a very great disadvantage. Under the new Regulation, the private lorries have to obtain a license in which the area they have to work in is specified. This area is to be fixed by the licensing officer taking into consideration the nature and the requirements of the business on which the lorry is to be used. Special permits easily obtainable may also be granted for working beyond this area when circumstances require it. This system, while offering full facilities for the use of private lorries on the business for which they are intended, makes it difficult for such lorries to carry goods for hire. The conditions of the license render it easier to, detect cases of infractions of the rule. In regard to public service lorries, the rules, while permitting casual trips when traffic offers, prescribe the area within which they shall ordinarily work. These permits are to be granted taking into consideration the co-ordination of goods traffic with the Railways and to secure this special conditions considered necessary in each case, such as these referred to in para. 14 above, may be attached to the license.

The Regulation also confers powers for the periodical inspection of road worthiness of motor goods vehicles, both private and public service.

III. Rail-Road Co-ordination.

17. A brief survey of the means of communication in the state, of the effects of motor competition on Railway transport, the measures adopted by the Government to regulate this competition hitherto and the measures adopted by the Railways themselves are necessary as a back-ground for the description of the system of co-ordination to be introduced under the new Regulation.

18. *Railways and Roads in Mysore.*—The total length of railways in the Mysore State is about 782 miles and of roads 5,754 miles. The following statement shows the position of Mysore in regard to the means of communication as compared with some other Provinces of British India:—

	Mysore.	Madras.	Bombay exclusive of Sind.	Bengal.	United Provinces.
1. The length of railways per 100 square miles of area (miles).	2·06	3·56	3·25	4·81	5·32
2. The length of roads per 100 square miles of area (miles).	19·62	26·80	23·00	55·40	35·00
3. Population per mile of railway (number).	6,385	10,700	8,740	14,117	9,500
4. Population per mile of road (number).	1,139	1,420	1,235	1,226	1,450
5. Percentage of metalled roads running parallel to railway within 10 miles.	90	61	60	36	63

19. *The existing state of Motor Competition with Railways.*—The total number of motor buses in the State was 583 in July 1935, of which more than 200 buses were running on roads parallel to the railways worked by the State in direct competition with them. The public service buses in Mysore run to definite timings; the fares charged by those running in competition with railways are approximately the same as third class railway fares, *viz.*, three to four pies per mile. The buses carry not only passengers but also parcels. Motor competition for goods traffic has not yet developed to any appreciable extent; there are no regular goods services plying for hire and carriage of goods is mostly done by owners of lorries who let them for hire on a contract basis or carry goods offering for a return load.

The Mysore Railways are particularly at a disadvantage in regard to competition with motors for the following reasons:—

They have, with the exception of the North-West Frontier Province, the largest percentage of metalled roads running parallel to the Railways amongst the Provinces in British India; more than 65 per cent. of their milage consists of lines newly constructed in regions of poor traffic; in most of these sections, the slow mixed train is an unfortunate necessity and fast service cannot be provided without heavy outlay and on some sections important stations are short-circulated by roads. That, with all these advantages in its favour, the motor traffic has not proved itself a much more serious competitor is due to the economic depression and also to some organic defects in the industry as carried on in the State.

20. *Estimate of classes to Railways on account of Motor Traffic.*—The coaching earnings of all the railways in Mysore, with the exception of that portion of the Bangalore-Madras section situated within the State limits for which separate accounts are not published, were Rs. 33,13,315 in 1933-34 against Rs. 41,64,492 of the peak year 1928-29; the corresponding goods earnings are Rs. 35,23.279 against Rs. 43,70,257. As there is no serious competition for goods traffic, the fall in this is almost entirely attributable to the trade depression. The fall in coaching earnings which is due both to depression and motor traffic is over 20 per cent. of which the larger portion is on account of motor competition. It may fairly be estimated that this loss is Rs. 5·2 lakhs or over 12½ per cent. of the coaching earning traffic or 6 per cent. of the total traffic.

21. *The existing system of regulation and control of competitive motor services is as follows:*—

(1) Licenses for public service motor vehicles on routes competing with railway are issued by the District Magistrates as on other routes.

(2) The number of motor services for which licenses are to be issued are usually fixed at a meeting convened by the District Magistrate of each District at which the railways are represented by the Traffic Manager.

(3) Buses plying for hire on railway competition roads are liable to double the ordinary milage cess, *viz.*, one anna per mile against six pies on other roads.

(4) Motor buses are not permitted to leave a starting station one hour before and one hour after the advertised time of departure of a passenger train.

(5) The issue of special permits for motor buses during festivals, fairs and other such like special occasions is strictly controlled. The railway department is asked to run extra trains and as far as possible to arrange for bus services from the railway station to the place of the festival and *vice versa.*

(6) No new licenses are issued on railway competition roads for buses without the previous orders of Government.

(7) Maxima and minima fares chargeable are also fixed.

22. *The measures adopted by the Mysore Railways to meet motor competition have been as follows:*—

(1) The Railways have increased the number of Train services by providing for frequent shuttle Trains for short distance traffic.

(2) They have also tried putting on light units such as Rail-cars on their busy sections to provide more frequent service.

(3) The shuttle services recently introduced are stopped between stations at convenient places close to important villages for setting down and picking up of passengers. This system of "intermediate halts" has proved very popular and has brought additional traffic to the Railways. There are no staff at these halts and the guard of the train books the passengers and collects tickets somewhat on the lines of conductors issuing tickets on bus services.

(4) Cheap third-class return tickets available for one day, two days week-end tickets and tickets at concession fares on occasions of festivals, etc., are issued.

(5) On the narrow gauge section where competition by motor bus is the keenest, the fares were reduced by 40 per cent. from 1st of January 1935. This has resulted in much larger number travelling by trains and during the short time it has been in force the increase in traffic has been sufficient to make up the loss consequent on the reduction in rates.

23. The road-rail competition is now a world-wide problem with which every country is confronted. The review of the measures adopted for solving the problem in forty different countries, as presented in the report prepared at the instance of the International Chamber of Commerce recently published, shows that every alternative, ranging from absolutely unfettered and unregulated competition to complete restriction and control of one form of transport agency to the advantage of the other or the control and working of all forms of transport by some central authority is tried in some country or other, with varying degrees of success. In fact, legislation in this matter is proceeding so rapidly in every country that any account of it is soon out of date. Among the most important of such legislative enactments not referred to in the "Road and Rail in forty countries" must be mentioned, the Road and the Railway Transport Act, 1935, of Northern Ireland already referred to, the amending Road Traffic Act, 1934, and the London Passenger Transport Act of 1934 of Great Britain. The Motor Carrier Act, 1935, of the United States of America and the decree of the 19th April 1934 on co-ordination of Road and Railway transport in France.

24. A comparison of the recent legislative enactments is a very interesting and instructive study, which cannot be included in this paper without making it unduly long. The Act of the United States of America is of special interest to India as conditions there are approximate, in the matter of transport, to those that will obtain in Federal India of the near future. This Act "vests jurisdiction over inter-state motor carriers in the Inter-State Commerce Commission, assisted by Joint Boards of State representatives". The purpose of the Act is set forth in Section 202, which declares that it is the policy of Congress "to regulate transportation by motor carriers in such manner as to recognise and preserve the inherent advantages of, and foster sound economic conditions in, such transportation and among such carriers in the public interest, promote adequate, economical, and efficient service by motor carriers, and reasonable charges therefor, without unjust discriminations, undue preferences or advantages, and unfair or destructive competitive practices, improve the relations between, and co-ordinate transportation by and regulation of motor carriers and other carriers; develop and preserve a highway transportation system properly adapted to the needs of the commerce of the United States and of the national defence; and co-operate with the several States and the duly authorised officials thereof and with any organisation of motor carriers in the administration and enforcement of this part."*

The decree of the 19th April 1934 of France is of some significance inasmuch as it brings under strict regulation and control the operation of

* Modern Transport, 7th September 1935.

public service motor vehicles, which in France were hitherto mostly uncontrolled.

25. *Basic principles of Rail-road Co-ordination.*—From the measures adopted in different countries and from their recent developments, it is possible to deduce the basic or general principles which should govern the regulation of land transport and its co-ordination with railways. They may be briefly formulated as follows:—

(i) Railways are an indispensible means of communication in every country.

(ii) No one type or agency of transport can meet fully the complex requirements of modern society. For a well-ordered system of transport, all agencies, railways, motors, aeroplanes, etc., are necessary.

(iii) Unregulated and unhealthy competition involves disastrous consequences for all forms of transport and should be avoided in public interests. "The public itself can only be the loser by such competition for it is the public which eventually has to bear the brunt of loss of efficiency in operation or of state subsidies which may become indispensible."[1]

(iv) This Regulation and control should not favour any particular type of transport as against another but should be with the object of placing the several agencies of transport on "a basis of economic parity", and allowing free play to healthy competition.

(v) With this end in view, unnecessary restrictions imposed on any one kind of transport to which others are not subject should be removed and obligations in public interests imposed on all alike. Certain regulations and obligations imposed on railways should be relaxed and regulations such as those concerning conditions of vehicles and other safety measures, requiring automobile public services to publish tariffs, to provide regular service and to carry traffic without discrimination between users, etc., should be imposed.

(vi) "A division of traffic between rail and road transport should be arrived at suited to their respective technical characteristics and thus consistent with the service which can be expected of them from an economic point of view. A close collaboration should be set up between rail and road transport, with a view to dovetailing them, wherever it may be necessary, and to organising combined transport on the cheapest and simplest basis possible."[2]

26. *Rail-road co-ordination in Mysore under the new Regulation.*—On the basis of these general principles, the Todhunter Committee found that the system of levying double the milage cess on motor buses on roads competing with the railways was not justifiable and recommended that it must be abolished. They also recommended that, on roads running close and parallel to the Railways, the Railway Department may be given the exclusive option of providing bus services. These services are to be subject

[1] Resolution, Congress of International Chamber of Commerce, Paris, 1935.

[2] Resolution, Congress of the International Chamber of Commerce.

to the same regulation and control as other buses. The Railway Department should be required to provide motor bus services on these routes to the frequency and the schedule of timings approved by the Board. The objects of this arrangement were to ensure that the public were not deprived of the advantages of either form of transport, that the routing of traffic by the cheapest agencies was facilitated and that the much needed collaboration between the two forms of transport was established.

27. In regard to the projects for the construction of new Railways, the Committee stressed that no new Railway should be constructed unless the volume of traffic offering was too much to be cleared by motors. They examined the several projects and came to the conclusion that none of them was paying and need be constructed. Some of the District Boards had been levying a Railway Cess for years and had formed funds for the construction of Railways in their districts. The Committee recommended that these funds may be utilised for the construction of new roads and the betterment of the existing ones.

The Government have accepted all the above recommendations of the Committee.

IV. Taxation of Motor Vehicles.

28. The system of taxation of motor vehicles that is in force in Mysore at present is analogous to that obtaining in many provinces of British India and has many drawbacks. In the first place, there is a multiplicity of authorities levying one kind of tax or other on motor vehicles. Thus, local bodies, such as municipalities, District Boards, etc., have all been levying taxes and tolls at varying rates and conditions, and under laws not intended for motor traffic. Secondly, there is not any system of provincial taxation, designed with the idea of dividing the tax burden on different classes of vehicles on some equitable basis. The Indian Motor Vehicles Act was not a fiscal measure but authorised the levy of fees for certain purposes. Mysore, like other provinces of British India which have not passed separate motor taxation acts, used these provisions for levying what were really taxes on some vehicles. A recent test case in Bombay has shown that this is not quite legal.

29. *System of motor taxation in Mysore under the new Regulation.*—The system of taxation under the Mysore Regulation seeks to remedy these defects. The Regulation takes away the powers of Municipal Councils to levy taxes on motor vehicles and taxation is centralised. Secondly, a system of taxation has been evolved in which an attempt is made to levy taxes on the use made of roads and on the wear and tear likely to be caused. The essential feature of the system of taxation thus evolved is that every class of vehicle should pay a certain basic tax, and another tax varying on the user, with provision for a higher rate in regard to vehicles which are likely to cause more than the ordinary wear and tear on the roads. The number of fees, etc., are reduced and taxes simplified as far as possible.

The details of this system of taxation in broad outline, are as follows:—

(i) Private motor cars and motor cycles pay a provincial basic tax called the "Vehicle Tax". The user tax is in the shape of tolls, all of which the owners may at their option compound by the payment of a quarterly composition fee.

(ii) Motor cabs pay a "service tax" based on seating capacity. The user tax is the same as for private cars.

(iii) Motor buses forming part of regular rural services are liable to a basic "service tax" based on the seating capacity of the vehicle. They are liable in addition to a road milage cess, at the rate of 6 pies per mile and are exempt from all tolls and fees.

(iv) Private motor lorries pay a basic "road tax" at scales varying on the unladen weight of the vehicle. Lorries for hire pay a higher tax on the same basis. Both private and public service lorries are exempt from tolls in the area covered by the permit.

In all cases a heavier scale of tax is prescribed for vehicles not entirely fitted with pneumatic tyres.

30. From the above description, it will be seen that tolls are not completely abolished. The Todhunter Committee considered this vexed question of tolls very fully and came to the conclusion that for reasons to be explained below it was not practical politics to do away completely with tolls.

31. That the system of tolls is not by any means an ideal method of recovering revenue from vehicles for the use of the roads hardly admits of any doubt. It is very vexatious and annoying for fast traffic like that of motors. It is also very wasteful in that a substantial portion of the revenue collected represents the profits of the contractor. This evil is "attributable to a very great extent to the system of farming, a system which has been abolished in respect of practically all other taxes and one that partakes of the policy of the ostrich. It is difficult in dealing with such a system of collection to prevent peculation. Therefore the Government, instead of attempting to control the peculation themselves, auction the right to collect the tolls and leave it to the purchaser at the auction to do his best. In such auction it may be urged that the interests of the road user are left out of account. The purchaser at auction of the privilege has no object except to secure as much money as he can during his short tenure. He spends nothing on his buildings. His barriers and lights are of a temporary description, his staff is ill-paid and often changing, and it is subjected to no proper control. As a result, motorists are held up for long periods by illiterate people who wear no uniform; barriers which are very dangerous in their nature are slung up just before the motorists reach the gates, and cartmen are made to pay exactions in excess of the authorised tolls."[1]

32. Undoubted as are the evils of the system, it has still to be recognised that tolls constitute the only practicable method by which a tax, graduated approximately to the use made of the roads, can be collected from all classes of vehicles in this country at present. An alternative to tolls will be to levy a vehicle tax on all classes of vehicles. While this is easily done in the case of motor vehicles, it is not possible or practicable to do so in the case of bullock carts. It will not be possible to identify

[1] Report of the Mysore Motor Transport Committee.

these bullock carts by any number plate as is the case with motor vehicles. It will also be difficult to detect or prevent misuse of the plates or licenses. The numbering of and the collection of taxes from thousands and thousands of carts scattered all over the country cannot be done without a large staff which will absorb a very large portion of the tax. Besides, the agriculturist already contributes a large portion of the amount spent on the construction, the upkeep and the maintenance of the roads and a vehicle tax on carts will fall unduly heavily on him, especially when he lives in villages away from the main roads and uses only the village roads. A system of a vehicle tax or any other tax on carts is thus open to many objections and cannot be easily worked. Secondly, tolls constitute a fairly satisfactory method of recovering interest and capital charges on new roads or bridges. But for tolls, the development of such new facilities would be much retarded. With all its imperfections, the system of tolls is still the only practicable method of recovering revenue for all classes of vehicles, however unorthodox this view may appear to be. In fact provinces like Madras which abolished tolls are now contemplating their re-introduction in the case of non-motor vehicles.

33. It is possible to remedy the defects of the system of tolls in many ways. Toll-gates should be under the control of a central authority. They should be more scientifically distributed and should as far as possible be worked departmentally and not farmed out.

It should be possible for motor vehicles to escape the annoyance of tolls by a composite payment.

The system of taxation adopted in Mysore is based on these principles. Under the new Regulation, the power of District Boards to levy tolls is abolished and all tolls are under the control of the Board. Important toll-gates are to be worked departmentally by the Board and are to be worked with staff of a much higher degree of education and tact than is the case with the staff at these toll-gates at present. The idea is also to utilise select and important toll-gates in the frontier as licensing offices to collect taxes and issue licenses to motor vehicles from other provinces visiting Mysore. It has even been advocated that petrol pumps should be arranged to be located close to toll-gates and that waiting rooms should be attached to these for the convenience of travellers.

In regard to tolls on motor vehicles, the system in Mysore allows composition in the case of motor cars and cycles. Motor buses and lorries are exempt from tolls, the taxes levied on them including the composition fee.

34. *The Road Funds.*—The taxes and tolls realised from road traffic are according to the Regulation, to be credited to a Road Fund constituted for the purpose. The Fund is to be credited with such other items as grants from general revenue for roads, etc., and the entire fund administered by the Traffic Board. It should be added that there has existed a road fund all along in Mysore and that the new Regulation only gives a statutory basis to this fund and entrusts the administration of it to the Board. All road revenue is in Mysore used only for the purposes of roads. In fact, the revenue from road traffic forms about 40 per cent. of the total expenditure on roads.

Mr. H. Rangachar: Though the subject of the paper which, it has been my privilege to submit to you, is the regulation and control of motor transport in Mysore, its scope is not, I venture to claim, so limited or local in its outlook and treatment of the subject matter as the title might

perhaps suggest. I have not attempted to give in my paper an exhaustive or detailed account of the Mysore system. The method adopted has been to indicate the most important and outstanding problems common to all countries which the advent of motor transport has created to make a comparative study of the measures tried or being tried in some of the important countries to solve these problems and in the light of this to give a reasoned description of the system adopted in Mysore.

2. Now, what are these problems? They are of three kinds. The first are administrative and cover matters relating to the regulation and control of motor transport such as registration of vehicles, licensing, regulations to ensure safety and measures for the control of public service motor transport. The second class of problems relate to the position which motor transport has to occupy as a member of the general system of transport in a country and its relation to other forms of transport, particularly Railways. Thirdly, there are the financial problems such as the ways and means of realising the extra funds required for the maintenance of roads and for making these fit for motors or in other words, that detestable thing called motor taxation.

3. I may offer a few brief remarks on each of the above aspects of this problem. The most striking feature of the system of administrative regulation and control of motor traffic, as it obtains in India, is the absence of a machinery, viewing the requirements of motor traffic as a whole and enforcing measures and policies common to the whole province or the country. The system of administration by District or Local bodies which was suited to the older local forms of transport with their very limited range is made to do duty for this traffic which knows no such limitations of provinces or countries. This shows that, in the matter of motor transport, progress of political and social organisation has not kept pace with that of invention. The result has been, in my view, the haphazard growth of motor traffic, its inefficiency as far as public transport service goes, its insufficient development and the failure to utilise fully the benefits of this new means to provide cheap transport in all parts of the country including rural areas.

4. The effects of the absence of such a machinery are still more noticeable and striking in the field of the regulation of motor transport in relation to other forms of transport, particularly railways. The characteristics of modern transport are its extreme complexity and the different forms of transport that are available for the same service. Is it in the public interest or for public advantage that there should be this multiplicity of agencies for transport? A little reflection will show that no one form of transport can fully meet the very complex requirements of modern transport. No nation can do without railways at present. They are most admirably suited for rapid transport of large volumes of traffic over long distances at cheapest rates, for the carriage of heavy and bulky traffic and of low grade traffic at rates which it can bear. Motor transport has been a very great factor in annihilating distance and in providing fast inland transport throughout the country at a total cost infinitely less than that of railways. But for motors, the immense benefit of fast transport would have been denied to large portions of every country. The advantages of motor transport are so great that they justify the remark of Herr Hitler that motors are the finest present made to humanity. As a railway man, I may perhaps say, he would have been more accurate if he had said *one* of the finest presents. Any way, all forms of transport, railways, motors

and aeroplanes are essential and each has a valuable and distinctive contribution to make to the system of transport in every country. It follows therefore from this that unrestricted and unregulated competition is harmful and that in the public interest, maximum benefit can be derived by using each form of transport in the sphere in which it is suited to render the most efficient service at cheapest cost. Though such delimitation is possible, there are still spheres in which each form of transport is of equal efficiency and competition is inevitable. In such "twilight Zones" a system should be devised which, in the words of a famous Minister of Transport of England, will "eliminate the abuses of the competition while retaining its incentive". All this co-ordination presupposes some agency, which, in national interests, strictly enforces co-ordinated policies and measures and where, one asks, are there such bodies anywhere in India? They are as conspicuous by absence as the proverbial snakes of Iceland. The point I wish to make is that such an agency is most essential for the proper development of the motor transport itself, and of other forms of transport. The experience of other countries has demonstrated that such an agency is necessary and that some kind of board or other is being set up in every country. I have given instances of these in my paper. The new law in Mysore sets up such a body, the principle adopted in its composition being that representatives of different interests connected with transport and those served by it should be entrusted with the task of managing it.

In the field of road-rail competition, the system in Mysore admits of a monopoly of road transport on roads adjacent to and parallel with railways being given to the Railway Department. The Department is expected to provide services as may be approved by the Board and these services are subject to the same regulation and control of the Board as other motor services.

I now pass on to the 3rd or the financial aspect of the problem and shall not be long at it. The discussion in this Congress has clearly demonstrated that the advent of motors has added considerably to the expenditure on roads, both on maintenance and construction. The motors have brought on the road a particularly vocal section of the population, with very exacting requirements in regard to the quality of the road. I have heard my engineering friends remarking with despair if ever a road can be in existence in which the motorist has not a host of sins of commission and omission to find. Yesterday, one of the Members here said that tarred roads had some deletrious effects on eyes; I had heard it said that tar had some adverse effect on lungs; but is it not possible, some of my harassed Engineering friends have asked, that driving in a car has some marked effect on the liver of the motorist? This does not particularly refer to the professional driver. An American defined a driver as one who is clever enough to run a car but at the same time clever enough not to own it. Such clever Drivers are getting less and less in number and there is scarcely anything at which the owner-driver has not reason to grouse. The roads—and some justifiably—tempt him to impress all the uncomplimentary adjectives in the English language to service. Recently a new type of mile stones giving distances between different important places on the road has been introduced in Mysore. An irate owner-driver who could not read a particular mile prominently asks why the P. W. D. in Mysore are so anxious to put the motorists through a course of Geography. Recently, new sign-posts have been put in on all the roads in Mysore but a motorist has announced his discovery in the columns of an esteemed daily paper in Madras that the sign-posts in Bangalore do not

enable you to get out of Bangalore when once you get into it and that some particular sign-post led you to that most admirable institution, the Mental Hospital. He assures us that it is not the place to which motorists need necessarily go. The wiles of photography are also impressed into service and pictures and scenes are reproduced with deadly effect. Some of you would have seen recently in a paper the fine photograph of what was called "a not infrequent scene" of a motor on road in some other province, in which the wheels of the motor and the hood, had for a change, exchanged their places, the wheels being in the air up on the top and hood down below on mother Earth. I must hasten to add that this picture was the handiwork of a most esteemed friend of ours who certainly is not of the class of irate motorists.

The truth is that the motorist is satisfied with nothing but a 1st class road and the financial resources at the disposal of the Engineers are too poor to admit of the provision of such roads on a large scale. The progress in the technique of road construction has to an extent lessened this burden and in this field the Road Congress has a very important part to play. Apart from it, additional funds are required and it is a vicarious satisfaction to the harassed road-Engineer, if the piper of the motorist is made to pay fully for the tune he calls.

The motorist, it must be conceded, does not deny that he has to pay but he insists and, quite rightly, that all the motor taxes should be used on roads, and that other road users must also contribute their share.

A system of motor taxes should therefore be one in which each class of road-user pays his portion of the tax, which should, to an extent be based on the use made of the road. A rational system of taxation—and this phrase reminds me of the remark of a cynic that a rational system of taxation was a contradiction in terms. According to him it was only a question of how thick the sugar coating on the bitter pill was before a tax became eligible to the appellation, rational. Be this as it may, a rational system of taxation should consist of the following two elements:—

(1) A basic tax for the franchise of the road system in the country, and

(2) An additional tax, varying on the user.

As I have stated in my paper, tolls constitute a fairly satisfactory method of exacting payment from different classes of vehicles on the use made of the road. Tolls have many imperfections but still they are necessary in the present condition of our country. My Madras friends will bear me out when I say that the abolition of tolls in Madras has landed them in considerable difficulties. At the same time it should be possible for any class of vehicle to escape the worry of tolls by a composite payment.

It is on these lines that the system of taxation in Mysore has been devised. I should have been glad to examine the question of the incidence of this taxation, whether motorist is paying more than his share in India and Mysore compared to other countries but this cannot be done within the compass of this paper. I should however add that Land Revenue forms a large percentage of the revenue in Indian Provinces and the agriculturist contributes certainly more than his share of general costs of roads.

I should in the end add that the proceeds of taxes on motors and tolls are credited to a Road Fund which is used wholly and fully on roads in Mysore.

With these few words, I beg leave to introduce my paper.

DISCUSSION ON PAPER No. 29.

Mr. Hughes: Mr. President and gentlemen—There is just one question which I want to ask and that is whether the author of the paper has considered any means of taxing self-propelled vehicles which do not use petrol. Vehicles using other fuels are now coming on to roads and they should be made to pay a tax equivalent to what they would pay if they consumed petrol.

Mr. K. G. Mitchell: Sir, I had not intended to speak on this paper. But in connection with the remarks on this paper I would like to draw the attention of my friend, Rao Bahadur Choudhry Lal Chand to the fact that most of the discussion regarding the possible segregation of motor and other transport has been prompted by the actual circumstances of the various classes of traffic and certainly not by a desire on anybodys part to see that rural population should be denied the use of the roads. The fact of the matter is that a large part of our problems in dealing with mixed traffic if not all our problems, is due to bullock carts, much more than to motor cars. So, when you say that this question of rural development has not come within the cognisance of engineers I do not think that that is a very fair statement to make. I must, in this connection, respectfully challenge what our President has said, that this Congress is not concerned with village roads. I think the Road Congress is concerned with the improvement of roads in general, irrespective of which roads they are and from what source they are financed.

Rai Bahadur Chhuttan Lal: I did not say that this Congress is not concerned with village roads. I said that this Congress is concerned with the utilisation of the road development fund and that the question of village roads may well come up for consideration in connection with the administration of the central revenues, *i.e.*, provincial as well as the Road Development Fund.

Mr. K. G. Mitchell: But I think that this Congress is entitled to discuss improvement of roads of any type.

Rao Bahadur Choudhry Lal Chand: My point was that this was within the province of this Congress and this Congress should discuss it.

Mr. K. G. Mitchell: I must thank Mr. H. Rangachar, very much for his paper because it is extremely useful to us. As you know, the problem of road-rail transport, which is not strictly our concern here, has arisen, and Mysore to some extent has advanced more than other parts of India in attempting to formulate regulations to control and regulate traffic. Because I know that these Regulations were being introduced here, about the time that the Congress was to meet, I asked my friend Mr. H. Rangachar to write his paper, and although we may not be able to discuss it at great length just now, it is a matter of great interest to us, both directly and indirectly.

Chairman: I should like to say just a few words on Mr. Rangachar's paper. In the first place we must congratulate the Mysore State on the formation of their new Traffic Board. I cannot honestly say that I congratulate them on their decision to retain tolls, but I am glad to know they have provided a means whereby they can be compounded. I am sure that those of us who came here by road will join with me in thanking the Mysore Government for having exempted the delegates arriving by road from payment of the new taxation which came into force on the 1st of

January, as also tolls. When we first heard that a new tax was coming into existence on January the 1st, we thought that this date had been specially chosen in order to catch the delegates arriving for the Conference, but as we have been let off payment, we were obviously wrong in arriving at this conclusion. If I may be permitted to do so, I should like to take this opportunity of expressing the hope that with the Traffic Board which has been set up, and the money that will be collected from the new taxes in the future, the State will endeavour very shortly to improve the condition of the road lying between Harihar on the Bombay-Mysore boundary and Bangalore which constitutes a section of the main road passing through India from Madras to the Afghan Frontier.

It is no exaggeration to say—and I hope that the Mysore Government will forgive me for taking this opportunity of making the statement—that the worst section of the road between Madras and the Afghan Frontier is undoubtedly the 170 odd miles which I have just referred to connecting Harihar and Bangalore. I quite understand the difficulties they are faced with in this respect, namely, the shortage of money for the purpose but as the State has instituted new taxes on motor vehicles in addition to retaining its toll system, I do hope that in the near future they will be provided with the necessary funds in this manner which will enable them to rectify the condition of this particular stretch of road. I do not suggest that they will find it possible to improve the road to the standard of the Punjab roads, which are now more or less dustless, but I hope that the surface will be improved to a standard which will be in keeping with the requirements of an important main road which connects the North to the South of India.

Another point that I would like to refer to which was made mention of by Rao Bahadur Choudhury Lal Chand a short time ago is the question of the segregation of bullock cart traffic in India. The Rao Bahadur spoke rather strongly on the subject and said it was not fair to the agriculturist for the bullock cart to be turned off the main road. This is one way of commenting on the suggestion, but I do not think it accurately describes the intention underlying any proposals which may result in the segregation of different forms of traffic (particularly those which move at different speeds) to different sections of the road. In this connection I do not know what the bullock cartwallas feel when motorists come up behind them and drive them off the road by the hooting of horns, or by curses or in any other manner. I imagine, however, that their feelings are very much the same as ours and that they object to being driven off the road just as much as we do and were I a bullock cartwalla, it seems to me I would be very grateful to the authorities if they provided me with a separate track where I could go to sleep in my cart and continue my journey thus without interference.

I think Burma has provided a solution to the problem because they have provided separate tracks for bullock carts alongside many of their roads and I gather from what I have seen myself and from discussions I have had with Mr. Hughes, that it is an economical proposition to have one track for the bullock cart and another for fast moving traffic, and bullock carts do not require to be forced on to separate tracks because they very quickly appreciate the advantage of having a track to themselves.

Another point I would ask this Congress to consider is the question of suitable provision for pedestrian traffic, whether it be in the cities or villages, or outside them. I think it is generally realised that the days

have gone when Road-Engineers can deal with the problem simply by saying "we will have a track of 20 feet, 30 feet, 50 feet, or 100 feet or more to meet the requirements of all traffic conditions". The Road Engineer of today apreciates that traffic problems now are complicated, particularly in India, by the movement of people, also vehicles, at different speeds.

In England the enormous number of road accidents are responsible for serious consideration being given recently to the provision of separate trackways for different types of road traffic, but in India we have fortunately not arrived at this stage as yet, and we need never do so if due consideration is given to the matter in time.

I take this opportunity of bringing this question before this Congress because I have noticed in my various tours throughout India, particularly in some of the Indian States I have visited in the early part of the year, that money is being spent on developing new roads which are designed in exactly the same way as they would have been many years ago before the introduction of motor vehicles. In other words large sums of money are being spent, but little heed is being taken to the requirements of modern traffic conditions, and pedestrians, slow moving bullock carts, and fast moving motor vehicles are all expected to make use of the same narrow track. In cases where new roads are under construction it is not so much a question of the cost, as that of a suitable design and I would urge that more consideration be given to this question than is apparent at present.

Dealing with the subject of the pedestrians, it is obviously quite impossible to expect the pedestrian to walk on the side of the road when the surface in the middle of the road is far superior. The pedestrian in this country has the disadvantage of being bare-footed and he must consequently be provided with a surface to walk on which is at léast equal to, if not better than, the surface demanded in road construction.

In Bombay the Western India Automobile Association in examining the question, sent out men on the roads to ascertain the views of pedestrians on the subject, and to their astonishment they found that pedestrians were under the impression that the 'Keep Left Signboards' intended for the direction of vehicular traffic, were meant to direct pedestrian traffic to the left instead of the middle of the road. When these pedestrians were asked why they did not use the footpaths that had been provided for them, they replied that they understood that footpaths in cities were intended for the benefit of the shopkeepers, and the reason they gave for coming to this conclusion was that shopkeepers get very annoyed if the footpaths in the vicinity of their premises are dirtied by pedestrians particularly in the early morning when they are being washed or swept preparatory to the opening of the shop. All this goes to show that there is urgent need for careful investigation of the whole question and I would request the members of this Congress who are devoting their time in trying to improve road communications in this country, to give serious thought to the important question of making provision for different forms of traffic on the roads, within the economical means which are available for the purpose, or as is sometimes the case, which can be made available for the purpose if the demand made is sufficiently insistent.

I will now ask Mr. Rangachar to reply to Mr. Hughes' question.

Mr. H. Rangachar: Mr. President and gentlemen—At the time the Bill was framed and the measures of taxation were fixed, we did consider

that point but we found that motor vehicles not using petrol were absolutely limited. At that time it so happened that there was scarcely a single vehicle not using petrol in the State. Besides, the system of taxation adopted by us is such that every vehicle which uses any form of mechanical traction is liable to taxes. It may be that the motor vehicles using petrol pay more because they pay indirectly the tax on account of petrol. But, to be honest, we are not so much interested in this tax. *The bulk of it goes elsewhere. Out of 10 annas, 8 annas go away somewhere* and even the remaining 2 annas we get in driblets. It is not a reflection upon the method of payment, but we naturally thought that we were not justified in penalising a man because he did not use petrol. Our interest in the petrol tax is only to the extent of 10 annas minus 8 annas less 15 per cent. of it. So, in view of the fact that motor transport not using petrol had not made any progress and in view also of the fact that our interest in the petrol tax was very, very limited, we did not think it worth while to tax the vehicles not using petrol, on a higher scale.

Chairman: In thanking Mr. H. Rangachar for his very interesting and instructive paper and in asking you to accord him your very hearty thanks, I wish to draw your attention that for the first time we have got a Divisional Superintendent of a Railway to address us on special Traffic Regulation, which is, I think, a most excellent sign. (Cheers.)

I am asked to advise you that we are assembling here at 10 o'clock tomorrow morning to discuss papers falling under Groups 6 and 8.

The Congress adjourned for the day, at 5 P.M.

Third Day; Saturday, January 11, 1936.

GROUP 6: BRIDGES (PAPERS NOS. 26, 27 AND 28).

CHAIRMAN:—RAI BAHADUR S. N. BHADURI.

The Congress re-assembled at 10 A.M. at the Sir Puttana Chetty Town-Hall—

Chairman:—We take up the papers in Group 6 and I request the author of Paper No. 26, Mr. M. G. Banerjee, Controller of Stores, Calcutta Corporation, to introduce his paper.

The following paper was then taken as read:—

Paper No. 26.

THE NECESSITY FOR A REASONABLY UNIFORM STANDARD LOADING FOR DESIGN OF CONCRETE BRIDGES AND A SUITABLE LOADING FOR SUCH AND OTHER TYPES OF BRIDGES ON HIGHWAYS IN INDIA.

BY

M. G. BANERJEE, B.A., B.E., A.M.INST.M. & CY. E., M.A.E., F.S.SC.,
Controller of Stores Corporation of Calcutta.

PART I.—DEVELOPMENT OF MOTOR TRANSPORT, VOLUME AND DENSITY OF TRAFFIC AND NECESSITY OF UNIFORM STANDARD LOADING FOR HIGHWAY BRIDGES.

India first witnessed the motor car in 1903. It was then considered as an object of luxury—a forbidden fruit for the public in general. The motor cabs placed on the streets of London in that year were also not very encouraging. But since 1906, when the cabs manufactured by the French House of Renault were first introduced in England, the people welcomed them as a convenient means of individual transport. America which now owns 75 per cent of the world's total vehicles and which, including Canada, manufactured 3,839,302 cars and 497,452 trucks (corrected upto 1925, *vide* "Facts and Figures of the Automobile Industry", 1926 edition) in the year 1925, had produced only 4 cars in 1896. Since then there has been a steady increase in production with the result that there were 25,814,103 motor vehicles in the United States in 1931 which represent one vehicle per 4·7 of the population. Out of these 3,233,457 vehicles are motor trucks of which 54 per cent are of 1 ton to 1·5 ton, 18 per cent between 2 to 2·5 tons and 14 per cent between 1½ and ¾ of a ton and the average radius of action of trucks in inter-urban traffic is computed at 100 miles. The total number of motor vehicles registered in British India up to the end of the fiscal year 1921 was 45,993 of which 31,934 were cars, 11,399 motor cycles and 2,660 trucks (heavy motor vehicles). This figure steadily went up to 1,09,978 on the 1st of January 1928 and this consisted of 73,698 cars and taxis, 21,986 trucks and auto buses and 14,294 motor cycles. But during the last five years the growth has been phenomenal and the number of motor vehicles registered in British India up to the end of March 1934, was 202,960 consisting of 141,415 cars, 40,427 heavy vehicles (lorries and buses) 21,118 motor cycles including scooters and auto wheels. The average number of motor vehicles imported into British India (including

Burma) every year on the basis of the last ten years' figure was 12,320. According to Mitchell-Kirkness report, the development has been shown in the table below.

2. The total number of vehicles in actual circulation in India including Burma according to the abovementioned report at the end of the fiscal years noted against each having regard to superannuation, is as noted below. This works out to 1 vehicle per 2,500 head of population.

Year.	Private cars and taxis.	Buses and lorries.	Total including motor cycles.
1923-24	32,740	5,884	47,456
1927-28	43,537	21,656	70,723
1931-32	61,392	36,083	122,051

The actual figures taken in the report are 70,000 cars and taxis, 45,000 buses and lorries and 7,500 motor cycles and the total taxes derived from all motor transport during the year 1931-32 were taken at Rs. 830 lakhs.

3. American statistics give the number of motor vehicles in British India in 1932 as 1,69,390 of which 1,13,820 were private cars, 43,345 auto buses and 12,225 lorries, or 1 vehicle per 1,883 of population. The number of rural buses or commercial vehicles which were plying on extra municipal roads in the 9 Governor's Provinces in 1930-31 was estimated at about 22,000.

4. During 1931-32 there were 75,123 miles of motorable roads in 9 Governor's Provinces (excluding Burma) of which 58,983 miles were metalled and 16,140 miles were unmetalled motorable roads. Out of these 13,227 miles were parallel to and within 10 miles of the rail roads. The total milage of road communications maintained by public authorities in British India up to 1931-32 was 74,541 miles of metalled roads and 1,89,971 miles of unmetalled roads or a total of 264,512 miles. Out of these 27,634 miles, 9,530 miles and 37,377 miles of metalled roads and 21,044 miles, 6,900 miles and 162,027 miles of unmetalled roads are maintained by the P. W. D., District and Local Boards and municipalities including cantonments notified areas and townships respectively. These figures exclude village roads and tracks which are not in charge of local bodies.

5. The annual expenditure on the construction and upkeep of roads in the 8 Governor's Provinces in India in 1929-30 was 609·5 lakhs of rupees against 467·6 lakhs in 1923-24, *i.e.*, in Madras, 165 lakhs; Bombay, 71·6 lakhs; Bengal, 58·8 lakhs; U. P., 65·8 lakhs; Punjab, 109·6 lakhs; B. and O., 51·7 lakhs; C. P., 50·3 lakhs and Assam 36·7 lakhs.

6. According to the census of 1931, the population of British India is 271,526,933 in an area of 1,096,171 square miles and spread over 269 districts comprising 1,698 towns and 4,99,359 villages. Besides, the various Indian States have 712,508 square miles of area with a total population of 81,310,845 in 877 towns and 1,97,472 villages. The total urban population of British India is 29,658,469 whereas the rural population amounts

to 241,868,461. The United States of America possess 3,009,066 miles of roads out of a world total of 9,225,000 miles or about one-third of the milage of the world. This represents 1 mile of road per square mile of the country. The States control 324,496 miles of roads. Of the State roads 209,000 miles are surfaced and the balance is still unsurfaced. Of the local roads 454,000 miles are surfaced and the rest is unsurfaced earth roads.

In Great Britain there were in 1931, 43,000 miles of classified roads (26,600 miles tested as 1st class and 16,400 miles as 2nd class) and 134,000 miles of unclassified roads or a total of 177,000 miles and the present annual expenditure for upkeep of the existing roads and construction of new ones is estimated at £60,000,000 against £23,700,000 of the pre-motor days. The number of motor vehicles in use there in 1931 was 1,570,173 of which 49,910 were motor buses and 365,554 were lorries.

7. France has got about 650,000 Km (403,845 miles) of roads and the French system is the most highly developed in the world as regards length of roads to area of country. France has got 120 Km length of road per 100 sq. miles, Great Britain 95 Km, United States 62 Km and Germany 45 Km and the annual road expenditure in France is estimated at Frs. 5,000,000,000. She had 1,722,368 motor vehicles (excluding motor cycles) in the beginning of 1932. There were 394,372 miles of roads in Canada in 1930 and annual expenditure on upkeep and new construction was 53,451,277 dollars. In the same country there were 1,206,836 motor vehicles in 1930, which works out to 1 vehicle per 8·6 of population. Germany was in possession of 274,000 Km (45,976 miles) of roads including city streets in 1931 and there were 684,000 vehicles in circulation there in the same year. If 792,000 motor cycles are included, this represents 1 vehicle per 43 of population and excluding cycles 1 vehicle per 94 of population. From these statistics, it is easy to discern that the development of motor transport in India in recent years has been pretty high but nevertheless it is in its infancy in comparison with the other countries of the world.

8. From the statistics given above it will be quite apparent that there has been steady increase in automobile traffic both for transport of passenger and merchandise in India since 1921 and the development of autobus passenger services throughout the country during the last 12 years has been phenomenal. Motor bus services have also penetrated into remotest villages where there are road facilities. Owing to this increased volume and intensity of traffic of mechanically propelled vehicles over roads in this country the importance of good and strong roads throughout the length and breadth of the land has been keenly felt and during the last decade many roads had to be improved and strengthened to cope with the modern fast and heavy traffic as far as funds permitted. To meet the needs of the ever increasing expansion in the use of motor vehicles as an agency of communication and transport of freight, a revolution has been wrought all over the world in the domain of high way improvements as will be evidenced by the statistics given before. America is going forward at an exceptional pace in this direction. Fifteen years ago there were practically no hard surfaced roads in America outside the towns and the progress made in construction during the last 15 years is remarkable and the public welcome the construction of hard roads everywhere. As an instance of the extent of the road construction being undertaken, you will be surprised to hear that in Pennsylvania State alone the programme of road construction for the year 1931 included the construction of no less than 1,200 miles of concrete road and

the rate of progress is so rapid that 1,000 feet of concrete road is laid in a day.

9. It is a matter of common knowledge as to what extent road traffic in India had dwindled after the advent of railways which were mostly built parallel to the existing trunk roads. With the development of railways the importance of roads for the transport of merchandise and passengers had been considerably reduced and with the exception of a few of the more important arterial and inter-district roads, country roads in general had been maintained and looked after in a casual and neglectful way. For want of proper upkeep some of the first class metalled roads which were once heavily trafficked and were the main trade routes, had degenerated into third class roads and the worn out metalled surfaces were covered up with earth and these roads were maintained as *kutcha* roads with an annual maintenance allotment of Rs. 50 to 100 per mile. After the transference of road cess to the Local Bodies, some new roads were constructed and improvements were effected in the existing highways but whatever improvements were made, were made on a parochial basis just to meet the local needs. These improvements in most cases are no doubt attributable to the growth of motor transport and to the consequent public demand for increased facilities for that transport to penetrate outlying areas. It is interesting to recollect that in 1920 even the District authorities were very much against the use of even 1 to 1½ ton trucks or buses on the country roads on the plea that the roads were neither suitable for carrying such a traffic nor were the bridges and culverts on them strong enough to bear the strain to be caused thereby, and as a District Engineer I was successful in convincing the District Magistrate with facts and figures that the intensity of pressure exerted by the light motor trucks is less than that exerted by a bullock cart running on narrow iron-tyred wheels, which roll at an angle with the axles and therefore a knife-edge pressure is exerted on the road surface. The total axle load in case of motor trucks is no doubt high but the intensity of pressure being less the damaging effect on the road is not higher than what it is with "*Bail*" (bullock) carts.

10. Recently, pneumatic tyred wheel equipment has been introduced and if it is popularised, the wear and tear of road surface will be appreciably reduced. For ordinary cart carrying a load of 15 to 20 maunds, one set of tyres with axle complete costs Rs. 148.

11. In 1929, I wrote a few articles in the "Indian Engineering" (now recast and incorporated in my book entitled "Notes on the design of culverts and bridges commonly adopted for the country roads in India") in which I dealt with the question of bridges in detail. I suggested then that improvement of road surfaces alone would not be of much avail for the growth of motor traffic and the trade that follows in its train, unless the roads are fully bridged. To keep up through-district, inter-district and inter-provincial communication at all times of the year, the road improvements must go *pari-passu* with the improvement and strengthening of the bridges of the old days and with the construction of new bridges over the natural barriers, *i.e.*, rivers, streams and other water courses, which are the missing links in the chain of highway communication. I sounded a call that the bridges which were to be built thenceforth should be designed according to some fixed standard *minimum* loadings, so that they might carry the loads hauled by heavy commercial vehicles to their full rated capacity with safety and that there would be no more need for imposing restriction either on speed or load on the bridges and the warning notices,

which are so often seen exhibited on these structures, would not have to be set up any longer.

12. I am glad that the Indian Road Congress is taking up this most important problem in this their second session. In Great Britain this question of fixing standard loading for highway bridges was tackled by the Ministry of Transport in 1922 and much has been said about it, since then. But India, as in most other matters, is behindhand in this respect by over 13 years. However it is better late than never.

13. Now the question arises what should be the minimum standard of loadings for road bridges in India. There is also at present no rational system of classification of roads in this country and they are classed as I, II, III, IV, etc., and allotments are made for annual maintenance according to this classification. Important metalled roads are generally classed as class I roads, gravelled roads and less important metalled roads as class II, improved *kutcha* roads and gravelled roads are classed as class III and village roads in charge of Local Boards are ordinarily classed as IV. The majority of the roads are looked after by Local Bodies and only roads of provincial importance and which are of interest to the realm are maintained by the Public Works Department. Out of 48,678 miles of roads under the Public Works Department in the whole of British India (including Burma, Baluchistan and other minor territories) no less than 21,044 are unmetalled. Classification of roads in the Madras Presidency can be seen from the following extract of the report of the Government of Madras to the Mitchell-Kirkness Committee:—

"The roads in the province are divided in 4 classes according to certain standards of specification and maintenance and for the purposes of administration and finance. Class I roads or trunk roads are metalled roads with metalling not less than 12 feet wide and maintained to a superior standard. With the exception of a relatively small milage which for administrative convenience is maintained by the Public Works Department class I roads are maintained by District Boards who are reimbursed by the local Government for their actual outlay subject to a prescribed maximum, the payment being made upon the certificate of the Superintending Engineer of the Public Works Department that the road has been properly maintained. The grant is usually made on a milage basis, Rs. 500 per mile per year being an average figure It appears that before the present depression, district boards were often spending more on trunk roads than they received from Government. Class II roads may be metalled or gravelled and are generally of the same typical section as class I roads; they are maintained by district boards who receive a fixed grant from Government on the certificate of the Collector of the district that the roads have been properly maintained. Class III roads may be metalled or gravelled but are maintained to a substantially lower specification than classes I and II; they are in charge of local bodies including Taluk Boards, who maintain roads of classes III and IV and are dependent for their resources upon a cess on the land revenue at the same rate as the district board cess. Within the taluks there are union board panchayats which administer a village or a group of villages and depend upon their own cess and on grants."

14. The report in respect of the Punjab is as follows:—

"Roads in the Punjab were reclassified about 8 years ago as follows—class I or arterial roads which are the important main roads of the province and are improved and maintained by the Public Works Department from provincial revenues. Class II which are the principal or most important roads in each district and are maintained by District Boards with grant-in-aid from provincial revenues both for maintenance and improvement, these grants being paid as a percentage of actual expenditure, the percentage having been fixed with regard to the financial and other circumstances of each district. And class III roads which are the less important roads of the district and are in charge of District Boards. In addition there is an unknown length, which may amount to as much as 50,000 miles of village roads connecting villages with each other and with the road system, which are the property of the villagers themselves and are nominally maintained by them but are generally in a very bad state of repair". In the other provinces the extra municipal

roads are classified as provincial or local accordingly as they are under Public Works Department or District Boards.

15. The Bombay classification is as follows:—

"For administrative purposes and for purposes of finance the roads are roughly classified into two divisions "provincial" maintained by Government and "local" maintained by local bodies. Recently, however, all roads in the Presidency have been reclassified in accordance with the tentative classification adopted by the Road Conference held in April 1930 for the purpose of applying the road development account as follows.

Class I—Roads of importance from the point of view of more than one province or state or more than one Commissioner's Division or in Madras, more than one revenue district within the province.

Class II—Roads of importance from the point of view of more than one Collector's district or in Madras, more than one Revenue Division and also roads serving as important feeders to railways, waterways to class I roads.

Roads of class I and II will be eligible for grants from the Central Road Fund provided they form part of a consistent plan of road development. Any other schemes submitted by Local Governments which do not fall within class I or II should be considered on their merits.

Class III—other roads.

These have further been sub-divided into 3 categories in each class—heavy traffic, medium traffic and light traffic but this sub-division is based upon general consideration and judgment and not generally, upon traffic statistics, the object being to obtain a classification which will stand for sometime and thus by estimating the traffic on certain roads to determine the category into which they will fall after the 1st stage of improvement."

16. The Bombay classification appears to be more rational.

For our purpose I would like to classify the roads as follows:—

(1) Roads in and around industrial centres.

(2) Main and arterial roads (they may be of all-India importance or of inter-provincial importance or provincial importance or of inter-district importance or district importance) including important feeders either to railway or to steamer stations.

(3) Roads in urban areas (extra-municipal).

(4) Roads in rural areas.

17. It is a known fact that India is not an industrial country but purely an agricultural one. But for the last few years, the industries have been making rapid headway and if this rate of progress is maintained, it is not idle to expect that within the next half a century her face will be entirely changed and she will take her rank among the foremost industrial countries of the world. It is no exaggeration to say that there is not another country in the world which possesses such a wealth of natural resources in the shape of raw materials of all kinds (both mineral and agricultural) as she does. And with the development of industry on modern lines, many places which are at present rural to the extreme will no doubt develop into crowded industrial towns. Sakchi (Jamshedpore) and Hirapore (Burnpore) are instances in point.

18. With this possible contingency in view the standard loads should be fixed. Moreover, the transport of heavy goods by motor trucks is gaining favour rapidly with commercial concerns and the unit loads carried by these vehicles nowadays are much heavier than could be anticipated a few years back. The businessmen will probably prefer to have their goods conveyed by roads at least for short hauls for obvious advantages: quickness in transport, less handling cost, more control over the carriers and less chance

of loss or breakage of goods. The motor cars have now cut short the distances and provided the people with easier and quicker means of communication between remote places and so the advantages of motor conveyance have been fully realised by the people and no longer have the railway a monopoly of freight and passenger transport. Nobody now thinks of travelling in a bullock cart or in a country boat at the rate of one and a half to two miles per hour or even by rail, if he can get an automobile to travel by. In Calcutta, inspite of so many existing means of communication, the best of which is the Tramway service, motor-bus service has been very popular and the Calcutta roads are now being flooded with these road carriers. At the present moment 1,086 taxi cabs, 580 motor buses and 3,001 lorries of varying capacities are actually plying on the roads of Calcutta City in addition to several thousands of private motor cars. Similar is the case with Bombay where the actual circulation of motor vehicles in 1934 was approximately 12,000. Time is also fast approaching when people will not be satisfied even with these types of quick locomotion by roads or by rails and they would very much like travelling by air and this is not a dream to expect that in the near future airways will become principal routes of communication of intelligence and of passenger transportation, if the cost of conveyance by air can be reduced appreciably. The time factor is of utmost consideration in communication now-a-days and it is an essential element in the economic prosperity of a country. Efficient communications develop social and political consciousness among the people of the rural areas.

19. Doubtless the high cost of petrol and other oil fuel, high local taxation and heavy import duties have put a check on the rapid growth of motor transport of this country. Otherwise it would have been far more vigorous by this time. The vehicles fitted with Diesel type of engines running on crude oil are becoming very popular nowadays owing to low running cost (*vide* Appendices I and II for comparative running costs of petrol and oil-engined vehicles) and if the cost of transport can be reduced and brought at least to a par with the cost of railway transport, it is highly probable, provided roads are improved on modern lines and put on a strong foundation capable of bearing the strain of heavy traffic, that in no time motor truck transportation will further expand and the highway which was neglected for about three quarters of a century, will come into its own again as a great artery of transport. The material, social and political prosperity of a country depends on quick and cheap transport both of men and merchandise from place to place and where such facilities are not adequate that country cannot prosper and keep pace with the onward march of other countries having these facilities. Aeroplanes, rail roads, steam vessels, automobiles and all other instruments of service have their respective spheres of activities and they all add greatly to the material prosperity of a country, enhance the standard of living and bring people of inaccessible regions to a new life of light and culture and open up a broad vista of progress of the world before them. Good roads are, therefore, a country's assets and money spent on road improvements should not, therefore, be grudged. Returns in the shape of economic progress from road building are far greater than the costs involved. Remember the days some two hundred years ago when it would take a person several weary weeks to cover a distance of a few hundred miles which could now be negotiated in a day. If in those days we were to get an intelligence or a message from our near and dear ones living in distant places it would have required some months and entailed a very high cost. Before the establishment of post

stations by the English East India Company in 1712 A. D. it took two to three months to send a message from Madras to Calcutta. With the establishment of post stations the time was shortened to thirty days. The cost of sending a message at the time from Fort St. George to Bengal was six "Fanams". Even in 1790 A. D., when some improvements were effected in the postal system, letters could be carried from Bombay to Calcutta in 26 days and to Madras in 17 days and from Madras to Calcutta in 19 days. In 1788 the charges for sending a single letter between Madras and Bombay were Rs. 2, and the charge on packets was at the rate of Rs. 4 per ounce.

20. I must also recall the incidents of recent years when there were strikes on the railways and the passengers had to be stranded on the way for a long time. If there had been communication facilities by roads these troubles would have been minimised to some extent. During and sometime after the war period, owing to scarcity of supply of railway wagons, there was coal shortage not only in Calcutta and Howrah but practically in the industrial areas all over the country and great difficulties were experienced not only by the mill and factory owners and other public utility concerns but by the public in general and transport of coal and coke by road from the Jherriah and Raneegunge coal fields had to be resorted to. but owing to restrictions imposed on the bridges on the Grand Trunk Road both on speed and axle weight, tremendous difficulties had to be encountered and heavy lorries could not be loaded to their full rated capacities and light lorries had to be engaged to carry these commodities at enormous transport charges. The present Howrah Bridge is also in such a weak condition that no lorry with more than 5 tons axle weight and with speed greater than 5 miles per hour is allowed to pass over it. However, this difficulty will be obviated with the construction of the new bridge which is to be taken up very shortly. This is really unsatisfactory and the sooner this state of affairs is mended the better it would be for the growth not only of motor trade but of the internal trade of the country as well. Grand Trunk Road is a road of all-India importance and it connects Bengal with Northern India and it is essential that this road should be bridged all over and the bridges should be capable of carrying the same units of loading and the reasons thereof are quite apparent. The economic value of a road cannot be fully exploited unless it is fully bridged so that the vehicles may ply with full loads all along and may not have to reduce the loads which they can safely carry in order to suit the strength of individual bridges.

21. In many places of this country also, not to speak of the other more highly developed countries of the world, owing to growth of highway transportation of both passenger and freight, railway earnings, specially from passenger traffic, have been adversely affected and this led to an open or disguised hostility by the railway concerns against the development of this new type of locomotion. In Great Britain, the annual loss of revenue between 1923 and 1929 was £10,000,000 in respect of passenger traffic and about £6,000,000 in respect of goods traffic. But it cannot be gainsaid that it is the duty of the authorities to provide the most economical and convenient means of transportation and to foster the growth of trade and commerce that follow in its train. In India there is a vast scope for both types of transportation growing side by side. India, as at present, is not a highly developed country so far as industry is concerned and she has very few roads fit to carry modern heavy mechanically propelled vehicular traffic. Out of 264,512 miles of highways in British India (uptill the end of 1932) approximately 1,411 miles of extra-municipal roads only have been surfaced

with either tar or asphalt, 154 miles either paved or grouted with bitumen and 37 miles have been paved with cement concrete either plain or reinforced, 72,989 miles have waterbound macadam surfaces and the vast majority, *viz.*, 1,89,971 miles are either unimproved earth or non-surfaced roads.

22. The authorities at the centre concerned with roads should draw up a ten-year programme of road improvements (if not done already) and the money accumulated from the petrol tax (which is at present about Rs. 100 lakh per annum) and other road vehicles taxes, which are earmarked for the development of the highways, should be released every year or every five years as is considered feasible for modernising the roads according to the plan chalked out, including the construction of bridges and culverts on the water courses passed through by them. The amount available is no doubt inadequate to meet the need which was estimated at 40 crores of rupees in 10 years but the financial difficulty has got to be tackled and loans should be raised, if necessary. The revenue accumulated in the Central Road Development Fund during the 1st quinquennium, *i.e.*, from 1st March 1929 to 31st March, 1934, was Rs. 512·71 lakhs. Deducting 10 per cent for reserve the entire balance of Rs. 461·44 lakhs (with the exception of 0·03 lakhs) was distributed to the various provinces and to minor administrations and Indian States for road development work including construction of bridges. A list containing as many as 62 important schemes of trunk road improvements including construction of several bridges both on main and subsidiary trunk roads of all-India and inter-provincial arterial roads was put forward before the Road Conference held in 1931. For maintaining a continuous and through land communication, bridges over the streams and rivers are a *sine-qua-non*. The highways selected for such improvements should in the first instance be the main and arterial ones, and then the important cross-country-roads, *i.e.*, the roads which run at right angles to the railroads and not parallel to them.

23. If this plan is adopted the roads will not only connect urban and other developed centres and important business marts with the railways but with one another. The cross-country roads will also serve as feeders to the railways and both road and rail transport will discharge their individual functions well and both will flourish in their own domain, being nurtured on the same soil like twin children nourished with the milk of the same mother, *i.e.*, one serving as an adjunct or ally of the other. Freight transportations for short hauls, *e.g.*, from the docks to the metropolis and from the metropolis to the towns and important marts within a short distance thereof and to the railroad stations, will be negotiated by motor vehicles and the railroads will be used chiefly for the long hauls and thus co-ordination of services both by roadway and railway will be established without any of the concerns having to stand as a rival to the other or to suffer loss or inconveniences. The village roads, which are in a deplorable condition now, should also be attended to by the District Boards, Local Boards or Union Boards, in order to enable the agriculturists to bring the produce of their fields to a better market. These roads should be made suitable for bullock cart traffic and connected to main roads. The improvement of these roads are of primary importance and is one of the most pressing needs throughout the country and should be effected with the utmost expedition. It is a happy sign that the Government of India have made a grant of Rs. 1 crore this year towards the improvement of rural communication and other village-welfare schemes.

24. India is a vast country with varying topographical, physical and climatic conditions and hence there is an insurmountable difficulty in making bridges and well-drained and improved roads of the same standard of strength all through and it is worth while to consider whether such improvements are needed at a prohibitive cost for the development of motor services. India's greatest need is a low-cost type of roads.

25. The Indian Road Development Committee of 1927-28 have concluded their ably written report as follows:—

"Our conclusion is that the development of the road system of India is desirable. It is specially desirable because it will make for the economic, social and political advancement of the rural population on which the future of the nation so much depends." They have also summarised their report, *inter alia*, as noted below:—

"The development of the road system in India is desirable for the general welfare of the country as a whole and in particular—

(*a*) for the better marketing of agricultural produce,

(*b*) for the social and political progress of the rural population, which will be advanced by the increased use of motor transport.

(*c*) as a complement to railway development."

26. I have only reiterated above what has already been said by many eminent men but my excuse for the repetition, is to bring home the importance of road development to those who have assembled here and who are principally responsible for its execution. It would not be out of place to mention here that in pre-railroad or steamship epoch when movements of passengers or goods were effected by country boats, pack animals or bullock and buffalo carts, the prosperity and cultural life, trade and commerce of India were in no way less flourishing than it is at present; and every student of history knows that from time immemorial India carried on an extensive trade and even colonial intercourse with both eastern and western countries of the world such as China, Japan, Western Asia, Africa and Europe and doubtless there existed adequate facilities for internal communication and transmission of goods according to the necessities of the age and the notions and practices then in vogue.

27. India is a country covered with a net work of water courses, which kept her internal trade flourishing since time immemorial even down to the present generation and the places which were situated on the banks of the navigable rivers naturally attained opulence and prosperity. The boats were the chief agencies of transmission of merchandise from one part of the country to the other and bullock carts and pack animals were the main agencies for land transport in all parts of India. Railroads and automobiles have stolen a march on these carrying agencies as they no doubt cut short the time of transference to an inconceivably low figure and this is the greatest incentive to the rapid growth of motor traffic all over the world. Quickness and cheapness attended with safety are the essential elements which conduce to the development of modern means of transportation. Quick locomotion not only annihilates the handicaps of time and space but is a sort of emolument.

28. The "good old days" of the Hon'ble John Company gives us an interesting account as to the boat expenses and time taken to negotiate the distances between Calcutta and the following places in the year 1781 A. D.

Boat hire:—

		Rs. A. P.	
For a "bugerow" of	8 dandis	2 0 0	per diem.
" "	16 "	6 0 0	"
" "	24 "	8 0 0	"
For a "woollock" of	4 "	22 0 0	per month.
" "	5 "	25 0 0	"
" "	6 "	28 0 0	"
For a boat of	250 maunds	29 0 0	"
" "	400 "	40 0 0	"
" "	500 "	50 8 0	"

Duration of voyage:—

From Calcutta to Murshidabad	25 days.	*(appears too long.)*
" to Patna.	60 days.	
From Calcutta to Almora	75 days.	
From Calcutta to Cawnpore	90 days.	
From Calcutta to Fyzabad	105 days.	
From Calcutta to Chittagong, etc.	60 days.	

One would now shudder to think of having this class of slow locomotion. To keep pace with the onward march of the world, India needs quicker means of locomotion. These improved facilities of transport are specially needed when there is so much economic depression in the country and the people have to run about for service and employment and the producers want to have better marketing facilities for their agricultural produce.

29. The importance of roads as a means of communication was recognised by the ancient Hindus and there were rules for the construction and maintenance of highways in Kautilya's *Arthasastra*, *Sukraniti*, etc. Well-paved and asphalted broad streets, ruins of a civilisation of a very high order were found in the excavations of Mohenjodaro (Sind) and Harappa (Punjab), dating back to 3500—2500 B. C. Thus the use of asphalt as a binding or a preserving material was known to the ancient Indians and the expression "bitumen" has its origin in the Sanskrit word "*Jatukrit*" which means pitch-producing. Though there were facilities for land travel in India during mediæval age, and also in the prehistoric period, the time and risk involved in travel were very great. Travel to distant places except on religious pilgrimage was probably rare and people were accustomed to stay near their own homes, living on the agricultural produce of their lands and other cottage industries. Boats were the chief means of communication between different places and where such facilities were not available people used to walk on foot or to ride on ox or to travel in bullock or ox drawn carts and carriages and various kinds of litters such as *doolies*, *choudoolies*, *palkies*, etc. European travellers of the 17th century left some interesting records about the cost and duration of land travel between certain parts of India. According to Tavernier (1652 A. D.), one could travel from Surat to Agra (396 Kos or 555½ miles) in a carriage drawn by oxen, in about 35 to 40 days. It took 30 to 40 days to travel between Agra and Patna (550 miles). The normal cost of transportation of goods was also very high and the first English commercial mission from Agra to Patna headed by Hughes and Parkar in 1620-21 A.D., had to spend Rs. 1¼ to Rs. 2¼ per maund of 62½ lbs. for transport of commodities from Agra to Patna. This rate also included trade risks from robbery and damage by rains.

PART II.—BRIDGES AND LOADINGS ADOPTED IN THE DIFFERENT PROVINCES OF INDIA.

30. The history of bridge building begins with the history of civilisation. The word "Setu" or bridge is found in the Vedic literature and the legend that Ramchandra, the great king of Oudh, built a bridge across the sea connecting India with Ceylon is known to every Indian. The necessity of bridges was felt by the primitive man. From time immemorial he used to cross a river on rafts or rough hewn canoes; then he began to fell trees across the streams and later tree-trunks were hewn and fastened together with ropes or thongs. Then *jhulas* or rope bridges were invented. These consisted of a rope or thong stretched across the stream or gorge with its ends tied either to tree-trunks or heavy stone boulders or similar fixed objects on the banks. A basket was then suspended from the rope and was moved to and fro on it by a smaller rope. Later two ropes were slung across the streams and small ropes were suspended from them at intervals and sticks of wood were tied to them to form a footway. These types of bridges are still being used by the hill tribes and many of them can be seen over the Himalayan streams. The place "Lachman Jhula" derived its name from the rope bridge used by Lachhmanji, the brother of King Ramchandra of the Sun dynasty in the 2nd era of the world, *i.e.*, in the "Silver age". The present form of suspension bridge has descended from these primitive bridges. Primitive log bridges have developed into properly designed timber beam or cast iron beam bridges which, in their turn, have now developed into rolled steel or Reinforced Concrete beam or built up plate girder and truss bridges. The pontoon bridges are the modern forms of boat bridges of ancient days. In Kashmir boat bridges are in use from very early times. The first boat bridge on the Bitasta, the construction of which was described by Bernier, was built by Probarsen II in the 2nd century A. D. Kashmir has also numerous permanent wooden bridges built between the 11th and the 15th century. Many examples of stone and timber bridges built during the Mogul period could be cited. The masonry arch bridges, *i.e.*, bridges of stone and bricks have now developed into steel and reinforced concrete arches of considerable spans. From the Sukraniti which is the political treatise of Sukracharya, it appears that the art of bridge building was known to the ancient Indian to some extent. And they were not unmindful of the importance of easy and through highway communications, otherwise that book could not have contained instructions such as:—

> "Bridges should be constructed over rivers. There should also be boats and water conveyances for crossing a river. Roads are to be provided with bridges."

31. There is at present no hard and fast rules either with regard to loadings or roadway to be carried by highway bridges and different engineers adopt different standards according to their own discretion and existing local conditions. When I was in charge of district roads, I saw and constructed many bridges with various kinds of loads and roadways of various widths, *e.g.*, 10, 12, 13, 14, 16, 18, and 20 feet. Ten feet width of roadway is sufficient for one lane of traffic and for two lanes 18 feet is in my opinion enough even now, as the overall maximum width allowed for motor vehicles is 7 feet 6 inches, though a 20-foot carriageway would be safer.

32. Let us now see what loadings are now being adopted in different provinces of India. Bridges on all roads in *Assam* with two exceptions are designed for a maximum load of 8 tons steam roller *plus* 25 per cent impact allowances (which in normal working conditions weighs 10 tons). The remainder of the span not so covered is taken as carrying a live load

of 80 pounds per square foot. On spans over 40 feet in length an earthquake load equivalent to an acceleration of 5 feet per second on the unloaded bridge and 3 feet on the loaded bridge is also provided for.

33. On the two roads, in regard to which an exception is made, a live load equivalent to a 10-ton road roller equal to 12 tons in working trim *plus* impact at 25 per cent and the remainder of the span covered with a live load of 90 pounds per square foot is allowed, or a stream of 9½-ton lorries *plus* 25 per cent impact and earthquake load as before. Wind loads, when they are considered, are taken at 50 pounds per square foot on the unloaded and 30 pounds per square foot on the loaded structure. The conditions in Assam are not likely to be generally applicable in other parts of India. Pile bridges (either solid steel or hollow cast iron pipes) are the more suitable types of bridges in Assam with the usual exception in the hills.

34. In *Bengal* there are no definite rules regarding loads to be adopted for highway bridges of different spans.

35. In the United Provinces the bridges are designed to carry the following loads:—

Class I.—Bridges on class I metalled roads—one 15-ton (16½ tons gross) steam road roller preceded and followed by a crowd. The weight of the front roller is taken as 6·6 tons and two back rollers, 9·9 tons with wheel base of 14 feet 4½ inches and wheel track 5 feet 4 inches. The width of each back roller is taken as 1 foot 6 inches and that of the front rollers

Fig 1

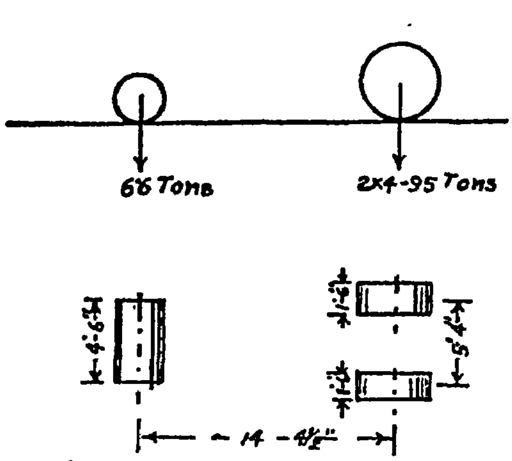


Diagram of 15 Ton Roller

4 feet, 6 inches. (Fig. 1.) The crowd load is taken from curve A, copied from Waddell's Bridge Engineering, page 117 (as in figure II, page 269).

For bridges on isolated metalled roads over which steam road rollers, traction engines or lorries are not likely to pass, the loads given under class II to be used.

Class II—bridges on unmetalled cart roads—crowd loads shown on curve C, to be used.

Class III—bridges on pilgrim and trade route bridle roads—crowd loads shown in curve B, to be used.

Class IV—bridges on less important bridle roads—crowd loads shown in curve D, to be used.

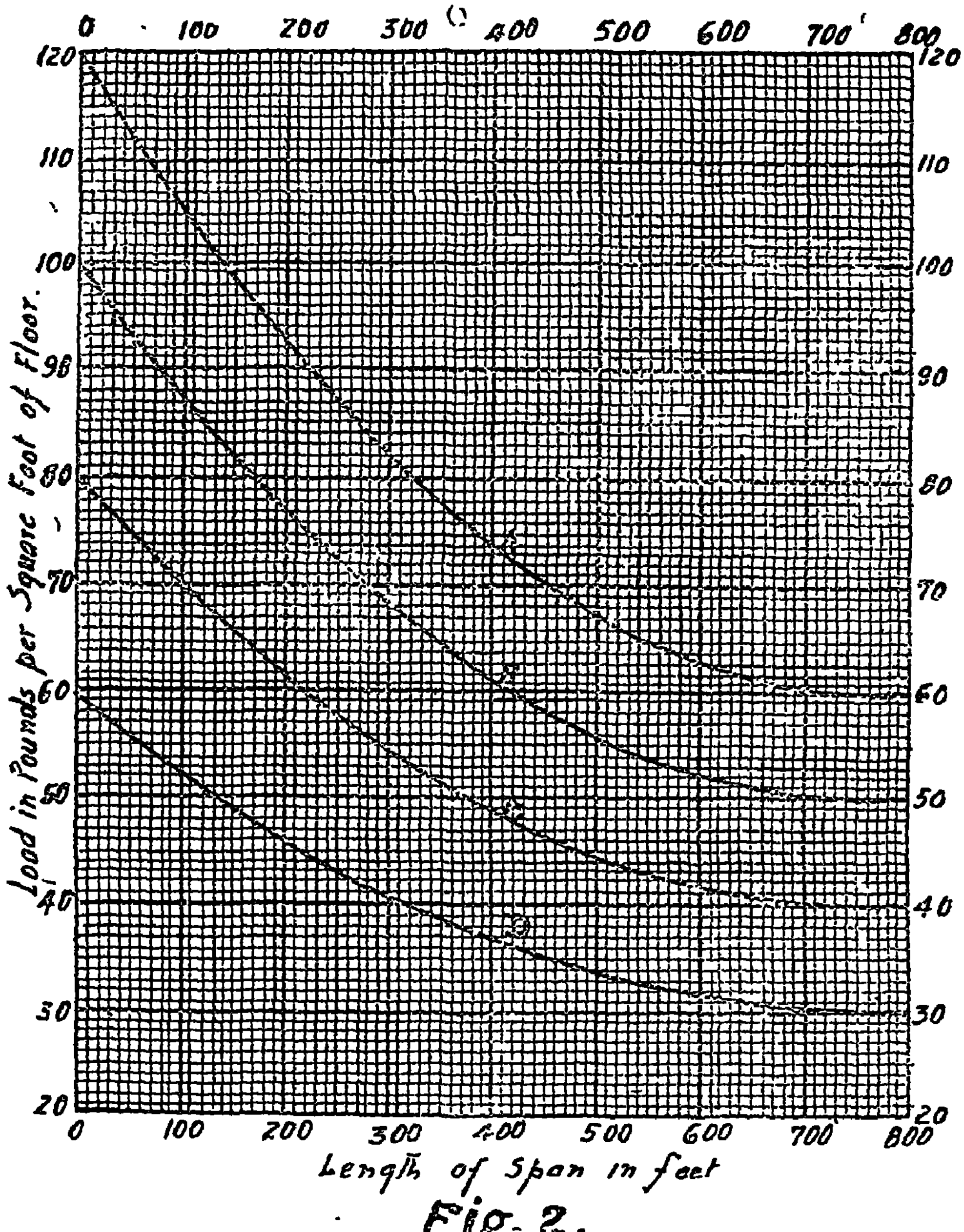


Fig. 2.

NOTE.

(*a*) Bridges on the approaches to temples and fairs are liable to be packed with a crowd. Such bridges, therefore, of whatever class or span must be capable of carrying load of 120 lbs. per sq. ft. Impact need not be allowed for, as it will not be obtained with a crowd so densely packed, and no allowance need be made for a steam road roller. A comparison should, however, be made in each case between the effect of a dead load of 120 lbs. per sq. ft. and the loading given in these rules.

(*b*) A 15-ton steam road roller, if allowance is made for impact, sets up higher stresses than a string of 8-ton motor lorries following one another at 60 feet intervals for all spans up to about 300 feet. For greater spans or heavier lorries, the lorries give the larger stresses, but it must be remembered that while the steam road roller may be preceded and followed by a considerable crowd. There would not be much pedestrian traffic on the bridge while a string of lorries was crossing it at high speed. For all ordinary conditions of traffic therefore a 15-ton road roller preceded and followed by a crowd may be taken as the maximum load obtainable.

36. **Impact.**—None of the foregoing figures allow for impact, which is to be found from Waddell's formula—

$$I = \frac{100\,A}{n\,L + 200}$$

where L = the length of span in feet covered by the load

$n = \dfrac{\text{width of decking}}{20}$

A = 1·25 for stiffened suspension bridges.

A = 1·00 for steel bridges with light wood open floors.

A = 0·75 for steel bridges with heavy solid floors.

A = 0·50 for reinforced concrete structures excepting spandrel filled arch bridges.

A = 0·25 for spandrel filled arch bridges.

I = co-efficient of impact.

37. The following coefficients of impact may be used for a 15-ton steam road roller for all widths of the decking up to 60 feet.

For suspension bridges	62½	per cent.
For steel bridges with open or light floors . . .	50	,,
For steel bridges with heavy floors	37½	,,
For reinforced concrete structures excepting spandrel filled arch bridges	25	,,
For spandrel filled arch bridges	12½	,,

In designing cross beams and flooring, live loads should be doubled to allow for impact. (*This is rather exorbitant.*)

38. When a mixed load, viz., crowd and steam road roller is assumed it simplifies calculations to deal with each separately. In considering the effect of the crowd the presence of the roller is ignored, but the axle loads of the roller are reduced by the weight of that portions of the crowd which the roller actually displaces. It is also stated that the above rules are only to be taken as guiding rules governing normal conditions. Special conditions will need special treatment. Bridges in the vicinity of large towns liable to be called on to carry tram cars or heavy motor lorries may be cited as instances where special loads must be assumed when designing (*vide* Chief Engineer's circular No. 20-P. W./2419-W., dated 1st November, 1920).

39. It is understood that a number of reinforced concrete bridges have been designed lately in the United Provinces to a uniformly distributed load of 200 pounds per square foot. The reinforced concrete, T—beam and trestle bridge of 5 spans of 24 feet 3 inches each which has been recently built over the Kali nadi on the Meerut-Bareilly road has been designed to carry 15 B. E. S. A. unit loading.

40. In the **Central Provinces** a 15-ton steam road roller with suitable allowance for impact for culverts and small bridges and 12 British Standard unit loading for larger bridges or spans of 50 feet and above are adopted.

41. In the **Punjab,** 10 units of British Standard loading is being adopted at present as the standard loading for all bridges on arterial and main roads. but in case of roads that carry or are capable of being

improved to carry mechanical transport, the adoption of the following standard loading is under consideration:—

Ten B. E. S. A. units up to a span of 80 feet and from spans of 80 feet to 300 feet a straight line reduction from 10 to 6 units *plus* impact addition according to the formula—

$$I = \frac{1}{2} \times \frac{65}{45 + L}, \text{ subject to a maximum of 50 per cent.}$$

42. In the **Bombay Presidency**, bridges on all provincial roads are designed to carry 12 units of B. E. Standard loading on each lane of traffic, *i.e.*, for every 10 feet width of roadway with 50 per cent. allowance for impact. The Chief Engineer, P. W. D., Bombay, is of opinion that for industrial areas 15 British Standard units should be adopted and 12 units for all main and arterial roads and 8 units for bridges on country roads.

43. In **Burma**, bridges on main roads are designed to carry 6 B. S. units which is equivalent to an 8-ton tractor followed by three 5-ton trailers per 10-feet traffic lane. For bridges near the frontier lighter loadings are adopted. In the districts, for steel bridges up to 100-feet span a standard loading is approximately equivalent to 4 B. S. units. For suspension bridges in the hills in undeveloped country an equivalent about 2 B. S. units is adopted. The Chief Engineer is of opinion that so far as Burma is concerned no heavier loading are likely to be necessary for many years, the requirements tending towards increased road mileage rather than towards heavier permissible loads.

44. So far as I could ascertain, the road bridges in **Bihar and Orissa** are now-a-days designed to carry a steam roller weighing 12 tons in working order *plus* impact addition as given below and a crowd load of 85 pounds per square foot covering the whole area of the roadway not occupied by the roller or alternatively a 10-ton motor lorry hauling a 10-ton trailer for each traffic lane. Two traffic lanes are taken in a bridge of minimum width 16 feet. The impact allowances are as follows:—

(*a*) For the Deck Slab or Trough plate flooring—40 to 50 per cent.

(*b*) For Cross girders and Stringers—33 per cent.

(*c*) Main girders and Trusses—25 to 30 per cent.

45. In the **Madras Presidency**, R/C culverts and beam bridges on B. Class roads are designed to the following specification.

Paragraph 4 (*a*) of Specification No. 124, *addendum* to Madras Detailed Standard specifications:—

"Loads:—Unless otherwise specified, designs shall be submitted in accordance with the B class loading, *i.e.*, providing for (1) one road roller [*vide* Fig. 2 (*a*)] 4·29 tons on front, wheel width 4 feet-1 inch, 3·94 tons on each rear roller width of each wheel 1 foot-4 inches and gauge length between front and rear axles 11 feet-3 inches together with (ii) one lorry 1·83 tons on each front wheel, 3·67 tons on each rear wheel, width of each rear wheel treated as 1 foot-4 inches and gauge length between front and rear axles 11 feet-3 inches together with (iii) 80 pounds per square foot on the

remaining portion of the span. (No crowd load shall be assumed within 5 feet-6 inches of rear axle nor 2 feet from front axle for either roller or lorry nor in the width of the bridge when the roller and lorry are in line in the width of the bridge) together with (iv) 30 per cent impact for all wheel loads both for the steel floor system and for the trusses."

46. It is understood that in the **North-Western Frontier Province**, a few reinforced concrete bridges have been constructed of late and these were designed to carry 10 units of British Standard loading with 50 per cent impact allowance.

47. The **Calcutta Improvement Trust** have constructed a few reinforced concrete bridges over the canals within the City of Calcutta very recently. The descriptions of and the loading adopted in these bridges are as follows:—

Name of the Bridge.	Type.	Degree of Angle of Skew.	Effective Span, in feet.		Width of carriage way in feet.	Foot path on each side in feet.	Remarks.
			Skew.	Square.			
1. Dum Dum Bridge (Near Belgachia Medical College).	Open Spandrel 3 hinged R/C arch.	72½	128	120	37	10	Provision to take tramway lines has been made.
2. Manicktola . .	Ditto .	75	128	...	37	10	Ditto.
3. Belliaghatta .	Ditto .	75	128	...	37	10	Ditto.
4. Narkeldanga .	Ditto .	Square	...	128	...	...	Ditto.
5. Alipore . .	Bow String .	Ditto	...	150	30	6½	
6. Chitpore . .	Ditto .	Ditto	...	78	57	10	38′—0″ roadway at centre for foot traffic and two 9′—0″ roadway out side girders for slow traffic.

All the arch bridges are three hinged with seven arch ribs braced up. The longitudinal and cross beams supported on columns standing on the arch ribs, support the bridge decking. All these arch bridges, I understand, were designed to carry a uniformly distributed live load of 133 pounds per square foot including impact.

48. The new Alipore bridge which is a bowstring type reinforced concrete bridge of 150 feet effective span having a 30-foot carriage way between curbs and two side walks 6 feet wide each carrying 3 pipe lines, (4 feet-3 inches diameter water main on one side and 3 feet 2 inches diameter water mains on the other side) below them on cantilevers outside the main girders, was designed to carry the following loadings or possible combination of loadings so arranged as to bring maximum possible stress on the member considered.

(*a*) The roadway to carry an uniformly distributed load, including impact, of 133 pounds per square foot.

(*b*) The footpaths to carry an uniformly distributed load, including impact, of 112 pounds per square foot.

S

(c) The pipe line to carry 4 feet-3 inches and 3 feet-2 inches water mains.

(d) The roadway to carry a combination of heavy lorries having 12-ton back axles and 4-ton front axles *plus* 50 per cent extra for impact.

(e) The deck slab to be capable of supporting an axle load of 18 tons including impact; the cross girders to be capable of supporting 3 lorries with 18 tons on each back axle including impact travelling abreast.

(f) A wind pressure of 40 pounds per square foot is to be provided for.

It seems to me that this is an extravagant design; we are to design bridges not for possible loadings but for probable loadings. This bridge was completed last year (1934).

49. The Chitpore bridge (78 feet span) which was constructed very recently (1935) over the Chitpore Canal is of the same type as the Alipore Bridge and the following loadings were adopted in its design.

(a) The roadway to carry an uniform distributed load of 220 pounds per square foot *plus* a transverse knife edge load of 2,700 pounds per foot run.

(b) The roadway slab to carry the above loads or alternatively the 25-ton axle of a boiler truck.

(c) The footpath slab to carry a load of 112 pounds per square foot.

(d) The main arch ribs to carry a load of 190 pounds per square foot *plus* a knife edge transverse load of 2,240 pounds per foot run on the roadways and 60 pounds per square foot on the footpaths.

(e) The hangers to carry a load of 220 pounds per square foot on the roadways *plus* a transverse knife edge load of 2,700 pounds per foot run of roadways and a load of 112 pounds per square foot on the footways.

All the above loads are assumed as having had the necessary impact already added thereto. Wind pressure at 40 pounds per square foot on one and half times the exposed side area of bridge is to be allowed for.

50. The above loadings are equivalent to the minimum standard loadings recognised by the British Ministry of Transport, *i.e.*, 15 British Standard Units with 50 per cent impact and are too severe for the roads of Calcutta. If road beds cannot bear the intensity of load for such a heavy vehicle, it is no use making the bridge strong enough to carry such a load. Taking the back wheel of the tractor as 2 feet wide and the spread of wheel load at 45 degrees to the normal and the surface contact of the wheel as 3 inches and depth of metal and foundation as 12 inches, the dispersion area of the road bed over which one back wheel load of 12½ tons of the boiler truck will spread $=4'\text{-}0'' \times 2'\text{-}3''=9$ square feet or a load of 1·4 tons per square foot, which the sub-soil cannot safely bear. The result will be damage to the road. In places where the thickness of macadam is less, the intensity will be greater, and the road bed will be

considerably overstressed. In places where ruts or bumps are to be met with, greater impact stress will be induced and the intensity of pressure will be further increased. The question of strength of roads should therefore be considered along with the strength required for bridges.

PART III—Heavy Motor Vehicle Regulations as affecting the design of bridges in the different provinces.

51. Before discussing about the live loads to be adopted we must see what limitations have been imposed on us by the Motor Vehicles laws of the land and what latitude has been allowed.

52. In the Southern States of America and in Canada maximum gross weight allowed on any one vehicle is confined to 28,000 pounds=12½ tons. But the bulk of the vehicles there are light type lorries and trucks, generally 1½ to 2 tonners. Steel tyred trucks are not in existence there and about 4 per cent of the traffic is on solid tyres; but the travelling speed is very high there. A point, which needs the most careful consideration is the maximum load which the road bed can safely bear so as to reduce breakage of roads constantly, which means a heavy recurring charge for their maintenance. I do not think, India needs a greater mileage of roads at present but the improvement of existing roads compatible with modern traffic has become a dire necessity. Cheap type of road construction, consistent with durability, suitable for light motor bus or lorry traffic all over the country is immediately wanted. If America can remain satisfied with the running of light type of lorries or trucks why should we go in for the British type of high-cost asphalt or tar macadamised hard roads or concrete roads either plain or reinforced, and build bridges capable of bearing a heavy traffic unit? The question of maintenance of roads, is a serious one and should be carefully thought about before launching upon extensive construction work or taking up schemes of great magnitude. It will tell upon the exchequer very seriously and the burden of upkeep alone will be too heavy to be borne. So we must be sure about our financial position and must see that the income derived from motor traffic equalises or at least bears a fair share of this additional expenditure in the improvement and up-keep of roads. Great Britain is a highly developed country with heavy traffic units and the average intensity of traffic on British Highways is the heaviest in the world and so the minimum loading for bridges as recognised by the Ministry of Transport of that country cannot be adopted for India. The Ministry of Transport's standard loading is equivalent to 15 units of B. S. I. loadings with 50 per cent addition for impact and this unit will be considered as too intensive for road beds of this country, generally, except in a few places of certain provinces, such as parts of United Provinces, Bombay, Madras, the Central Provinces, and Chota Nagpur, etc., where roads are mostly carried on unyielding hard *substrata*.

53. Let us now see what limitations are imposed.—

Rules 37, 39, 40 and 41 of the Madras Motor Vehicles rules (as amended up to 31st December, 1928), and which are applicable to the running of heavy motor vehicles, *i.e.*, motor vehicles exceeding 2 tons in weight when unladen, are reproduced below *in toto*. These rules limit the maximum axle weight, the maximum length of a train of vehicles, the maximum width, the maximum speed, etc.

MADRAS MOTOR VEHICLES RULES.

(As amended up to 31st December, 1928).

Conditions for the use of Heavy Motor Vehicles.

37. No person shall cause or permit a heavy motor vehicle to stand or be used in a public place or shall drive or have charge of a motor vehicle when so used unless the following conditions are satisfied :—

(1) (i) The axle-weight of any axle of heavy motor vehicle shall not exceed the registered axle-weight.

(ii) The registered axle-weight of any axle of a heavy motor vehicle shall not exceed eight tons and the axle-weight of a trailer shall not exceed four tons.

(iii) The sum of the registered axle-weights of all the axles of a heavy motor vehicle shall not exceed twelve tons.

(2) The tyres of each wheel of a heavy motor vehicle, unless the tyres are pneumatic or made of a soft or elastic material, shall be smooth, and shall, where tyre touches the surface of the road or other base whereon the heavy motor vehicle moves or rests, be flat :

Provided that the edges of the tyre may be bevelled or rounded to the extent in the case of each edge of not more than half an inch.

Provided also that—

(i) If the tyre is constructed of separate plates the plates may be separated by parallel spaces which shall be disposed throughout the outer surface of the tyre so that nowhere shall the aggregate extent of the space or spaces in the course of a straight line drawn horizontally across the circumference of the wheel exceed one-eighth part of the width of the tyre;

(ii) the driving wheels of a heavy motor vehicle shall be cylindrical and smooth-soled or shod with diagonal crossbars of not less than three inches in width nor more than three-quarters of an inch in thickness, extending the full breadth of the tyre, and the space intervening between each such cross-bar shall not exceed three inches;

(3) the width of the tyre of each wheel of a heavy motor vehicle shall be determined by such of the following conditions as may apply to the circumstances of the case; that is to say—

(*a*) the width shall in every case be not less than five inches;

(*b*) the width shall be not less than that number of half inches which is equal to the number of units of registered axle-weight of the axle to which the wheel is attached.

The unit of registered axle-weight shall vary according to the diameter of the wheel, and the rules set forth in the subjoined scale; that is to say—

(i) If the wheel is three feet in diameter the unit of registered axle-weight shall be 7½ hundred-weights.

(ii) if the wheel exceeds three feet in diameter, the unit of registered axle-weight shall be 7½ hundred-weights with an addition of weight in the proportion of one hundred-weight for every 12 inches by which the diameter is increased beyond three feet; and in the same proportion for any increase which is greater or less than 12 inches.

(iii) if the wheel is less than three feet in diameter, the unit of registered axle-weight shall be 7½ hundred-weights with a deduction of weight in the proportion of one hundred-weight for every six inches by which the diameter is reduced below three feet, and in the same proportion for any reduction which is greater or less than six inches :

Provided that this clause shall not apply to any tyre which is pneumatic or which is made of a soft or elastic material.

(4) The diameter of a wheel of a heavy motor vehicle, if the wheel is fitted with a tyre which is not pneumatic or is not made of a soft or elastic material, shall not be less than two feet.

(5) A heavy motor vehicle shall, when measured between its extreme projecting points, be of a width not exceeding seven feet six inches and no heavy motor vehicle or train made up of a motor vehicle with one or more trailers attached to it shall be used in any public place if such motor vehicle or train exceeds 36 feet in length. The height of a heavy motor vehicle when loaded and measured from the ground level to the highest point of the hood or load, whichever is higher, shall not be less than two feet.

(6) The heavy motor vehicle shall be constructed with suitable and sufficient spring between each axle and frame of the heavy motor vehicle.

Conditions for the use of Trailers.

39. No person shall haul, by means of a heavy motor vehicle, in any public place more than three trailers at a time, nor any trailer, unless the following conditions are satisfied.—

(i) Each trailer shall satisfy the conditions laid down for heavy motor vehicles as to registered maximum axle-weight, tyre, width of tyres, size of wheels, width of vehicle and springs save that, in the case of a trailer, the registered maximum axle-weight shall not exceed four tons and that the minimum width of tyre shall be three inches save in the case of trailers not exceeding one ton in weight unladen which shall be exempted from the prescribed requirements as to width of tyre;

(ii) each trailer attached to a heavy motor vehicle shall have a brake approved by the registering authority and each trailer shall carry upon it a person competent to apply the brake efficiently, provided that, where the brakes upon the motor vehicle to which any trailer is attached are so constructed and arranged that neither of them can be used without bringing into action simultaneously the brake attached to the trailer, or if the brakes of the trailer can be applied from the motor vehicle independently of the brakes of the latter, this rule shall not apply;

(iii) the heavy motor vehicle shall not at the time be in use as a public conveyance.

Driving on Bridges.

40 (i) Where any duly constituted authority affixes or sets up in suitable and conspicuous positions, on each approach to a bridge, forming part of a highway, notices stating the carrying capacity of the bridge which, as regards all their contents or subject matter, are clearly and distinctly legible and visible by persons approaching the bridge, the owner of a heavy motor vehicle, the combined registered axle-weight of which exceeds the carrying capacity of the bridge as specified in the said notice, shall not cause or suffer the motor vehicle to be driven, and the person driving or in charge of the motor vehicle shall not drive the motor vehicle upon the bridge.

(ii) The owner of a heavy motor vehicle shall not cause or suffer the motor vehicle to be driven and the person driving or in charge of a heavy motor vehicle, shall not drive the motor vehicle, upon a bridge forming part of a highway at any time when another heavy motor vehicle is on the bridge, if the combined weights of the vehicles exceed the carrying capacity of the bridge.

Speed Limits.

41. No person shall drive a heavy motor vehicle in any public place at a speed exceeding seven miles an hour.

Provided that—

(*a*) if the weight of the motor vehicle unladen exceeds three tons or

(*b*) if the registered axle-weight of any axle exceeds six tons, or

(*c*) if a trailer is attached to the heavy motor vehicle, the speed shall not exceed five miles an hour.

Provided also that—

if heavy motor vehicle has all its wheels fitted with pneumatic tyres or with tyres of a soft or elastic material, the speed shall not exceed—

(*a*) twelve miles an hour, where the registered axle-weight of any axle does not exceed six tons,

(*b*) seven miles an hour, where such registered axle-weight exceeds six tons.

BENGAL MOTOR VEHICLES RULES.

Corrected up to March 31, 1929.

(These rules do not apply to Calcutta including its suburbs and Howrah.)

PART I—*Preliminary.*

Rule I—(1) In these rules "Motor-car" includes all Motor-Vehicles other than Motor Cycles, road rollers and vehicles which run on rails.

(2) "Heavy Motor-car"—means a motor-car exceeding 2 tons in weight when unladen.

(3) "Light Motor-car" means a motor car not exceeding 2 tons when unladen.

(5) "Trailer" means a vehicle drawn by a heavy motor-car.

PART II—*All motor Vehicles.*

11. The width of a motor-vehicle or trailer as measured between its extreme projecting points, shall not exceed 7 feet 6 inches.

16 No, motor vehicles shall be driven at a greater speed than—

(1) 15 Miles an hour within any Municipal area if a light motor-car or motor cycle;

(2) 10 miles an hour if a heavy motor and 8 miles an hour if the axle weight of any axle of the heavy motor car exceeds six tons or if it draws a trailer.

The provision of this rule shall not apply to such motor vehicles as may be specially exempted by the Local Government in this behalf.

PART III—*Heavy Motor cars.*

Rule 26—(2) The registered axle-weight of an axle of a heavy motor-car shall not exceed 8 tons and the sum of the registered axle-weights of all the axles of a heavy motor-car shall not exceed 12 tons.

Rule 27—(1) (a) In all cases the driving wheels of heavy motor vehicles shall be fitted with resilient tyres.

(*b*) The non-driving wheels, if fitted with resilient tyres, shall, if the axle-load is or exceeds 4 tons, be fitted with twin tyres.

(*c*) The non-driving wheels if fitted with resilient tyres shall be smooth and without any projection and shall not be constructed of separate plates separated by any spans whatsoever.

(2) The width of non-resilient tyres of each wheel of a heavy motor-car shall not be less than six-inches and the tyres of the wheels on the same axle shall be of equal width.

(3) The permissible axle-load shall not exceed 5 hundred-weight for each inch in width of the combined width of the two tyres of the axle in question.

28. The diameter of the wheels of a heavy motor-car, if they are fitted with a tyre which is not pneumatic or made of a soft or elastic material, shall not be less than 2 feet 6 inches.

29. *Restriction of using heavy motor cars on the bridges.*

(2) No owner of a heavy motor car, the axle-weight of any axle of which exceeds six tons, shall cause or suffer the car to be driven and no person driving or in charge of any such car shall drive the car upon any bridge at any time when another heavy motor-car is on the bridge.

31. (1) No motor-car, which is used either as a stage carriage or otherwise for the conveyance of passengers for gain or hire, shall draw a trailer.

(2) Not more than one trailer shall be drawn by any motor car. (There may be some special reasons, if permission for drawing more than one trailer by a motor-car is to be obtained from the District Magistrate.).

33. The axle-weight of an axle of a trailer shall not exceed 4 tons.

35. *Width of Tyres of trailers.*

To every trailer exceeding one ton in weight, when unladen, the wheels of which are fitted with tyres which are not pneumatic or made of soft or elastic material, clause (c) of sub-rule (1) and sub-rules (2) & (3) of Rule 27 shall apply with the substitution—

(*a*) of 3 inches for 6 inches as the minimum width of the tyres and

(*b*) of references to the axle-weights marked upon the trailer in pursuance of Rule 32 for the references to registered axle-weights.

Rules applicable to the Darjeeling District.

49. Motor cars not exceeding 20 horse power and 21 hundred-weight in weight when loaded are allowed to be driven on the roads in Darjeeling.

CALCUTTA AND HOWRAH MOTOR VEHICLES RULES 1930.

PART II.

Rule 18.—The width of a motor vehicle or trailer as measured between its extreme projecting points shall not exceed 7 feet 6 inches.

PART III—*Axle weights.*

Rule 61—(2) The registered axle weight of an axle of a heavy motor car shall not exceed eight tons and the sum of the registered axle weights of all the axles of heavy motor car shall not exceed 12 tons.

Provided that a heavy motor car—

(*a*) Drawing a trailer which is so partially superimposed upon and attached to the heavy motor car that at all times the weight upon the rear axle of the heavy motor car shall exceed the weight upon the axle of the trailer or

(*b*) is provided with six road wheels mounted on these separate axles under a rigid frame and that the distance between the middle axle and the rear axle is not greater than 4 feet 6 inches and is not less than the exterior diameter of the tyre of the largest wheel :—

the sum of the registered axle-weights shall not exceed 16 tons or

(*c*) is provided with six road wheels of which two are mounted on the front axle and four on the rear axle, the latter wheels on each side being mounted one in front of and one behind the axle, the registered axle-weight on the rear axle shall not exceed 12 tons and the sum of the registered axle weights shall not exceed 16 tons.

Tyres.

Rule 52—No heavy motor car shall be licensed unless the car is fitted with pneumatic or resilient tyres of a soft and elastic material in all wheels (with certain proviso for exception).

Rule 53.—Length :—The maximum overall length of a heavy motor car measured from the dumb irons or if there are no dumb irons from the foremost part of the vehicle exclusive of the starting handle must not exceed 27 feet 6 inches in case of a four wheeled vehicle and 30 feet in case of a rigid frame six-wheeled vehicle.

Provided that if a heavy motor car draws a trailer which is so partially imposed upon and attached to the heavy motor car that at all times the weight upon the rear axle of the heavy motor car shall exceed the weight upon the axle of the trailer the maximum overall length of the heavy motor car and the trailer so attached shall not exceed 33 feet.

Rule 56—Restrictions on the use of heavy motor cars upon bridges.—Same as in other provinces.

Rule 58—(1) Trailers—No trailer shall be used unless it is fitted with pneumatic or resilient tyres of a soft and elastic materials, provided that the Commissioner may, for special reasons to be recorded in writing, permit non-resilient tyres, if he is satisfied that their width and diameter is such that the vehicle will not damage road surfaces.

(2) The maximum length of a trailer excluding the coupling shall be 14 ft., provided that the Commissioner may for special reason permit a trailer whose length is in excess of 14 feet.

(3) The coupling shall not be more than 4 feet in length.

(6) Not more than one trailer shall be drawn by any motor car—(Provided that the Commissioner may for special reason permit more than one trailer to be drawn).

(7) A heavy motor car which exceeds 26 feet in overall length or which has more than 4 road wheels shall not draw a trailer.

59 (2) The axle weight of an axle of a trailer shall not exceed 4 tons.

Provided that if a heavy motor-car draws a trailer which is so partially superimposed upon and attached to the heavy motor car that at all times the weight upon the rear axle of the heavy motor car shall exceed the weight upon the axle of the trailer, the axle-weight of the axle of the trailer shall not exceed 6½ tons.

41 Speed—

No motor vehicle shall be driven at a greater speed than (1) (a) (ii)—15 miles an hour—in case of heavy motor car (*i.e.*, a car of over 2 tons unladen weight) if all the wheels of such vehicles are fitted with pneumatic tyres.

(*b*) 12 miles an hour—in case of a heavy motor car (not being a motor omnibus) if all the wheels of such vehicle are fitted with soft or elastic tyres other than pneumatic tyres.

Provided that if the axle weight of the axle of the heavy motor car exceeds 6 tons in weight or if it draws a trailer the speed of such heavy motor car shall not exceed 8 miles an hour.

(*h*) Conditions of fitness of omnibuses.

Rule 166. The total weight laden and complete for service must not exceed 9 tons and the weight of any one axle must not exceed 5½ tons. In the case of approved types of rigid frame six-wheelers too laden weight must not exceed 12 tons, and the weight of any one axle must not exceed 4½ tons (112 lbs. to be allowed for each passenger as well as the driver and conductor in calculating the total laden weight).

167. Maximum overall length not to exceed 26 ft.

168. The overall width must not exceed 7 ft. 6 inches.

169. The over hang behind the rear wheels measured from the centre of the rear axle shall not exceed 7/24ths of the overall length of the vehicle.

BIHAR AND ORISSA MOTOR VEHICLES RULES.

(Government Notification No. 4043-P. dated 23rd November 1929).

PART IV—Rules to regulate the use of heavy motor Vehicles in B. & O. (Heavy motor vehicle means a motor vehicle which if fitted with pneumatic tyres weighs over two tons unladen and which if not fitted with such tyres weighs over 1 ton unladen.)

Rule 67-(2) No heavy motor vehicle fitted with other than pneumatic or solid rubber compound tyres shall be registered, if its weight unladen exceeds 3 tons or if the tyres of the wheels are fitted with any projection likely to cause damage to the surface of the road.

Rule 70 (1) (ii)—The registered maximum axle weight of any axle of a heavy motor vehicle shall not exceed 5 tons.

(iii) The sum of the registered axle-weight of all the axles of a heavy motor vehicle shall not exceed 7½ tons.

(5) The overall dimensions of a heavy motor vehicle shall not exceed the following when measured between its extreme projecting points :—

Width 7 ft. 6 in.
Length—4 wheeler—28 ft.
6 do. 30 ft.

The height shall not exceed 12 ft. measured from the ground to the highest point of the vehicle including the load.

A train consisting of a heavy motor vehicle or vehicles with one or two trailers attached shall not exceed a total length of 75 ft.

73. Trailers—No person shall haul by means of a heavy motor vehicle in any public place more than two trailers at a time, nor any trailer unless the following conditions are satisfied.

(i) * * * In case of a trailer the registered maximum axle weight shall not exceed 2½ tons, when unladen and 5 tons when laden, and that the minimum width of tyre shall be 3 inches.

74. Restrictions same as in other provinces about the running of motor vehicles over bridges.

Rule 25. Speed limits—(ii) No heavy motor vehicle drawing a trailer shall be driven at a greater speed than 8 miles per hour.

THE PUNJAB MOTOR VEHICLES RULES 1931.

(Includes road rollers and other mechanically propelled vehicles.)

Home Department letter No. 20622, dated the June 1931.

Part IV—(Special Rules applicable to heavy motor vehicles).

77. (a) No heavy motor vehicle shall be used in any public place with more than 3 trailers attached to it.

(b) No heavy motor vehicle or train made up of a heavy motor vehicle with one or more trailers attached shall be used in any public place if such motor vehicle or train exceed 75 ft. in length.

80. The speed at which a heavy motor vehicle is driven in any public place shall not exceed 7 miles an hour.

Provided that—

(a) if the registered carrying capacity of the heavy motor vehicle exceeds 3 tons, or

(b) if the load transmitted to the road by any wheel exceeds 3 ton, or

(c) if a trailer is attached to the heavy motor vehicle the speed shall not exceed 5 miles an hour.

Provided also that, if the motor vehicle has all its wheels fitted with pneumatic or resilient tyres the speed at which the heavy motor vehicle may be driven on any public road shall not exceed,

(a) twelve miles an hour, where the registered axle weight of any axle does not exceed 6 tons;

(b) Seven miles an hour where such registered axle weight exceeds 6 tons.

81. This rule restricts areas within which and the routes on which a heavy motor vehicle may be driven.

These rules do not apply to Hill Roads within the province and there are special rules applicable to Hill Roads.

Part VI-E—Additional specifications for Heavy Motor Vehicles and trailers.

139. The axle weight on any axle of a heavy motor vehicle shall not exceed 8 tons and of any trailer 3 tons.

140. The sum of the axle weights of all axles of a heavy motor vehicle shall not exceed twelve tons, and of a trailer 5 tons; provided that, if the vehicle is the property of any local authority, the sum of the axle weights shall not exceed 16 tons.

141. Every heavy motor vehicle of more than 5 tons weight when laden shall be fitted with pneumatic or resilient tyres on the driving wheels. This rule does not apply to tractors.

145. (1) The width of the tyre of each wheel of a heavy motor vehicle or trailer, unless the tyre is pneumatic or resilient shall be determined by one of the following two formulas;

(a) $\frac{}{7\cdot 5-X} = T$ in cases where the diameter of the wheel is 3 ft. or more;

and

(b) $\frac{2W}{7\cdot 5-\frac{X}{2}} = T$, in cases where the diameter of the wheel is less than 3 ft.

Where W = Total weights in cwts., on each wheel;

X = the amount measured in feet by which the diameter of the wheel is more or less than 3 ft., and

T = the width of the tyre in inches;

Provided that—

(a) the width of a tyre of any heavy motor vehicle shall be not less than 6 inches; and

(b) the width of a tyre for a trailer shall be not less than 3 inches.

(2) The size of all resilient tyres shall be such that the loads imposed upon then shall not exceed the limits prescribed by the manufacturers of such tyres.

144. The diameter of a wheel of a heavy motor vehicle or trailer, if fitted with a tyre which is neither pneumatic nor resilient shall not be less than 2 feet.

145. The maximum overall width of any heavy motor vehicle or trailer shall not be more than 7 feet 6 inches.

Appendix 5—Roads.

1. For the purpose of restricting motor traffic on roads in the Punjab, roads are divided into three classes, *viz.*, A, B & C. Class A roads will include all roads metalled with stone metal of adequate hardness, such as the major portion of the Grand Trunk Road, and may be used for all classes of motor traffic, subject to the provisions of the Punjab Motor Vehicles Rules 1931. Class B roads will include all roads metalled with Kankar, brick or soft stone, and may be used by the Motor Vehicles not exceeding 30 cwt. in carrying capacity; provided that six-wheeled motor vehicles fitted with low pressure pneumatic tyres and not exceeding two tons in carrying capacity will be permitted to use the road. Class C roads will include all unmetalled roads and may be used by Motor vehicles not exceeding 30 cwts. in carrying capacity; provided that six-wheeled motor vehicles fitted with low pressure pneumatic tyres and not exceeding two tons in carrying capacity will be permitted to use the roads.

U. P. MOTOR VEHICLES RULES, 1928.

Under Indian Motor Vehicles Act 1924 (Act VIII of 1914).

Part III—Rules applicable to Heavy Motor Vehicles.

59. *Axle weights.*—The axle weight of any axle of a motor vehicle shall not exceed 8 tons, and the axle weight of any axle of a trailer shall not exceed 3 tons. The sum of axle-weights of all the axles of a heavy motor vehicles shall not exceed 12 tons, and of a trailer 5 tons; provided that if a vehicle is the property of any Local authority, the sum of the axle-weights shall not exceed 60 tons.

60. Every motor vehicle of more than tons total weight when laden shall be fitted with resilient tyres on the driving wheels; provided that this rule shall not apply to tractors.

64. *Width and length of vehicles.*—A heavy motor vehicle or a trailer attached to a heavy motor vehicle shall when measured between its extreme projecting points, be of a width not exceeding 7'-6" and no heavy motor vehicle or train made up of a heavy motor vehicle with one or more trailers attached shall be used in any public place if such motor vehicle or train exceeds 75 feet in length.

66. *Trailers* :—(3) No heavy motor vehicle shall be used in any public place with more than 3 trailers attached to it.

BOMBAY MOTOR VEHICLES RULES.

(Corrected up to December 31, 1928).

(Applicable to the whole of the Bombay Presidency, including Aden).

Rule 20. Speed :—(1) No motor Vehicle shall be driven at a greater speed than 20 miles an hour within the limits of :—

(*a*) the city of Bombay and

(*b*) Any Municipality or Cantonment to which this Sub-rule may be applied by the orders of Government.

(4) The speed at which a heavy motor vehicle is driven on any public road shall not exceed 8 miles an hour

Provided that—

(*a*) if the weight of the motor vehicle unladen exceeds 3 tons, or

(*b*) if the registered axle-weight of any axle exceeds six tons, or

(*c*) If a trailer is attached to the heavy motor vehicle, same as hereinafter provided the speed shall not exceed 5 miles an hour.

Provided also that—

If the heavy motor vehicle has all its wheels fitted with pneumatic tyres or with tyres of a soft or elastic material and does not draw a trailer or draws a trailer which is so constructed and by partial superimposition attached to the heavy motor car that at all times the weight upon the rear axle of the heavy motor car shall exceed the weight upon the axle of the trailer and which trailer has not more than two wheels in contact with the ground, such wheels being fitted with pneumatic tyres or with tyres made of a soft or elastic material, the speed at which the heavy motor vehicle may be driven on any public road shall not exceed—

(*a*) 12 miles an hour where the registered axle-weight of any axle does not exceed six tons.

(*b*) 8 miles an hour where such registered axle-weight exceeds six tons.

37. (ii) The registered maximum axle-weight of any axle of a heavy motor vehicle shall not exceed 8 tons and the axle-weight of any trailer not conforming to the requirements laid down in the 2nd proviso to rule 20(2) shall not exceed 4 tons.

(iii) The sum of the registered axle-weights of all the axles of a heavy motor vehicle shall not exceed 8 tons and the axle-weight of a heavy motor vehicle with a trailer conforming to the requirements laid down in the 2nd proviso to Rule 20(2) when the sum of such registered axle-weights shall not exceed 16 tons.

42. *Width and length of vehicle.*—A heavy motor vehicle and any trailer attached to any such heavy motor may, when measured between its extreme projecting points, be of width not exceeding 7 ft. 6 inches and no heavy motor vehicle or trailer attached to it shall be used on any street or road if such motor vehicle exceeds 36 ft. in length.

44. No heavy motor vehicle used on any street or road shall have attached to it more than one trailer except when allowed by the licensing authority in accordance with rule 53.

47. Restriction for the use of motor vehicles on bridges.

48. No Motor vehicle is to be driven on a bridge when there is another motor vehicle or locomotive on the bridge, if the combined weights of the vehicles would exceed the carrying capacity of the bridge (same as in other provinces).

Special Rules for Traction Engine.

53. *Size*—(1) A traction engine and any trailer attached to any such traction engine may when measured between its extreme projecting points be of a width not exceeding 8′-6″ and no traction engine made up of a locomotive with one or more trailers attached to it shall be used on any street or road, if such vehicle and trailers exceed 75 ft. in length.

(2) The weight of a traction engine shall not exceed 14 tons.

55. *Maximum limit of 3 trailers.*—No traction engine used on any road or street shall have attached to it more than 3 trailers.

EXTRACT FROM THE ROAD TRAFFIC ACT, 1930, GREAT BRITAIN.

(Taken from Kemp's Engineer's Year Book for 1932).

Generally, the Act repeals all legislation which might have been incompatible with its provision in respect of the control of traffic and regulations for vehicles and loads.

New Classifications of Motor Vehicles.

Motor vehicles are now grouped in the classes :—

Heavy Locomotives (not load carrying), the unladen weight exceeding 11½ tons.

Light Locomotives, not load carrying, unladen weight 7¼ to 11½ tons.

Motor Tractors, not load carrying, unladen weight not exceeding 7¼ tons

Heavy Motor cars, not being vehicles classified under the Section as Motor Cars, unladen weight exceeding 2½ tons.

Motor cars, not being motor cycles not invalid carriages—

(1) Constructed solely for the carriage of passengers and their effects, adapted to carry not more than 7 passengers besides the driver: fitted with tyres of the prescribed type; weight not exceeding 3 tons;

(2) in any other case, not exceeding 2½ tons.

Provision as to Tyres.

Subject to a few exceptions—

(1) On and after January 1, 1933, locomotives and tractors and their trailers must be fitted with pneumatic or rubber tyres; (2) heavy motor cars and motor cars exceeding one ton in weight unladen; (*a*) registered after January 1, 1933. must be equipped with pneumatic tyres, (*b*) must all be so equipped by January 1, 1940; (3) every trailer constructed after January 1, 1933, drawn by a motor car or heavy motor car, must be equipped with pneumatic tyres, and all such must be so equipped by January 1, 1940. Exceptions (*a*) land implements, agricultural trailers, (*b*) constructed before January 15, 1931, and (1) designed for horses and cattle; (*c*) (*ii*) designed for furniture and similar household effects.

The maximum width 7 ft. 6 in. of a heavy motor car registered on or before January 1, 1932, may be exceeded by 6 inches if this increase is necessarily due to conversion to use with pneumatic tyres.

Locomotives.—If the soft tyres obligatory after January 1, 1933, are in section, these may not be separated by more than ¾ in., and the aggregate of spaces must not exceed 6 in. This regulation does not apply to agricultural locomotives having smooth-soled steering wheels tyres, not less than 5 in. tread, and driving wheel tyres not less than 12 in. wide, smooth-soled, or shod with diagonal bars not less than 3 in. wide, nor more than ¾ in. thick, nor more than 3 in. apart, nor to agricultural tractors, similarly, but steering wheel tyres 2½ in. and driving wheel tyres 6 in.

Maximum Dimensions.

(Not verbatim but sections given for reference.)

(5) Four-wheeled vehicle, 27 ft 6 inches; more than 4 wheels, 30 ft., articulated vehicle 33 ft.; 8—wheeled articulated vehicle registered before January 1, 1931, 36 ft. (20) Locomotives, overall width 9 ft. (26), Motor tractor, width 7 ft. 6 in. (27) Overhang, 6 ft. (31) Heavy Motor Car, width 7 ft. 6 in. (39) Motor car width 7 ft. 2 in. (32) and (40 *a*) Overhang in both cases seven twenty-fourths of length. (51) Trailer, length exclusive of drawbar, 22 ft., unless normally used for indivisible loads of exceptional length, or being a land implement or part of an articulated vehicle. (52) Overall width (other than a land implement), 7 ft. 6 in.; a trailer in use by a travelling showman before January 15, 1931, 8 ft. 9 in.

Maximum Weights.

(21) *Locomotive.*—Unladen 15½ tons; additional 1½ tons if having a permanent fitting as a crane or winding drum, and independently, 2 tons if fitted with soft tyres. Not more than three quarters of the total weight may be carried by any two wheels.

(33) *Heavy Motor Cars.*—Four wheeled 7¼ tons; 6 wheeled, 10 tons; more than 6 wheels 11 tons (permanent fitting allowance) as (21).

Other Regulations.—(56) The maximum weight of a locomotive must not exceed unladen weight by more than three tons.

(57) The maximum weight of all the trailers drawn by a locomotive may not exceed 40 tons.

(58) The sum of the weights transmitted to the road by the wheels of a trailer and of a tractor of heavy motor car drawing it must not exceed 22 tons.

(59) *Heavy Motor Cars.*—Maximum weights; of a single wheel in a transverse line, 4 tons, of any two of four, 8 tons; of any two of more than four, 7½ tons. Total weights: all wheels, 4 wheelers, 12 tons 6 wheelers, 19 tons; limit, 22 tons.

Exception—(Regulation of 1931) Steam vehicles, limited to 12 m. p. h., with or without trailer; registered (*a*) before January 1, 1932, 14 tons, (*b*) on or after January 1 1932, 13 tons if all wheels are fitted with pneumatic tyres.

Heavy Vehicles on Bridges.

The Bridge authority of any bridge may, by means of conspicuous notices, prohibit the use of the bridge: (*a*) by a vehicle exceeding a definite maximum laden weight, not less than five tons, (*b*) in respect of the laden weight of a vehicle when travelling at a more than a definite speed. Provision is made for appeal to the Minister, who may order a prohibition or restriction to be removed or may refer the matter to an arbitrator.

Maximum Speed limits (Road Traffic Act, 1930)

Extracts of the rules are given below.—

2. *Goods Vehicle* :—

(1) When not drawing a trailer—

(*c*) (*i*) Heavy Motor cars (if all the wheels are not fitted with pneumatic tyres but are fitted with soft or elastic tyres; and (*ii*) if all the wheels are fitted with pneumatic tyres—20 miles per hour.

(*d*) Do. if the wheels are fitted with soft or elastic tyres—16 miles per hour.

(2) When drawing a trailer—

(*a*) If all the wheels of the drawing vehicle and trailer are fitted with pneumatic tyres and for articulated vehicles, if fitted with soft or elastic tyres—16 miles per hour.

(*b*) If the wheels of both the drawing vehicle and trailer are fitted with soft or elastic tyres—8 miles per hour.

(3) In any other case—5 miles per hour.

3. *Locomotive and Motor Tractors* :—

(1) Heavy locomotive (exceeding 11½ tons weight)—

(*a*) Within any city, town or village—3 miles per hour.

(*b*) Elsewhere—5 miles per hour.

(2) Light locomotive (7¼ to 11½ tons weight)—

(*a*) When not drawing a trailer or not drawing more than two trailers, if all the wheels both of the locomotive and of any trailer drawn by it are fitted with soft or elastic tyres—8 miles per hour.

(*b*) In any other case—5 miles per hour.

(3) Motor Tractors (up to 7¼ tons weight)—

(*a*) When not drawing a trailer and if all the wheels of the tractor are fitted with soft or elastic tyres—16 miles per hour.

(*b*) When drawing a trailer and if all the wheels both of the tractor and of any tractor drawn by it are fitted with soft or elastic tyres—8 miles per hour.

(*c*) In any other case—5 miles per hour.

PART IV.

What should be the standard loadings for highway bridges in India.

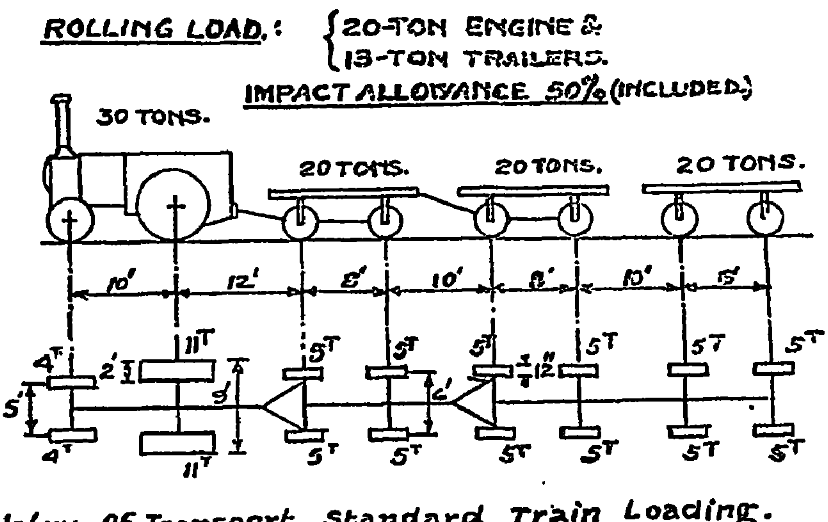
54. Let us now see what loadings are prescribed in different countries for highway bridges.

(1) Great Britain (Ministry of Transport's Loading 1931).

The Ministry of Transport's standard minimum loadings for road bridges in Great Britain is based on a 20-ton traction engine drawing three 13-ton trailers with 50 per cent. addition for impact. It is in effect equivalent to the heaviest dead load that is permitted for a train of vehicles having steel tyres. (The regulations under the Road Traffic Act of 1930, however, enforced the use of pneumatic or rubber tyres on all vehicles including locomotives and tractors from 1st January, 1933). It is thought that this loading will provide for all normal traffic conditions for very many years to come. Permissible working stresses both for steel and reinforced cement concrete bridges have also been specified. The equivalent loading curve of 1931 was brought out as a simplified form of the standard load of 1922, as stated above. Previous to 1931 bridges of large span had been designed to special loadings, but now the equivalent uniform load curve covers spans up to 2,500 feet. This is applied to bridges on all types of road there and in normal cases no distinction is made between *steel* and *concrete* structures. In districts where heavy indivisible loads in excess of 16 tons have to be dealt with the bridges are to be designed of greater strength accordingly. The standard width of carriage way on bridges is fixed at 10 feet, per line of traffic. Fifteen units of British Standard Institution loading is very similar to the Ministry's Standard loading, assuming 50 per cent. impact addition in both cases, but is little used there except in the case of bridges designed by railway companies.

The Ministry of Transport's standard load for highway bridges (1922) is shown in the following figure:—

FIG. 3



Ministry Of Transport Standard Train Loading.

NOTE.—The bridge shall be assumed to be carrying such standard loads or parts of standard loads as will produce the maximum stress in any bridge member or material under construction, provided that in any train of loads there shall not be more than one engine per 70 feet of the span of the bridge and that the distance between the centre lines of two adjacent trains of loads shall be taken as 10 feet in normal cases where the width of the carriage way is a multiple of 10 feet. Where a smaller multiple is adopted (but not less in any case than 8 feet), it shall be assumed that the distance between the centre lines of two adjacent trains of loads is reduced to the dimension of the lesser multiple so adopted. The "overall width" of 9 feet shown on the diagram must then be assumed to be reduced so as to leave 1 foot clearance between the wheels of two adjacent trains.

(Ministry of Transport, Roads Deptt., June 1922.)

This note was modified in April 1927 as follows:—

The bridge shall be assumed to be loaded with such standard train or parts of standard train as will produce the maximum stress in any bridge member, provided that in any line of trains there shall not be more than one engine per 75 feet of the span of the bridge and each standard train shall occupy a width of 10 feet. Where the width of the carriage way exceeds a multiple of 10 feet, such excess shall be assumed to be loaded with a fraction of the axle loads of a standard train. The fraction to be used shall be the excess width in feet divided by 10.

Equivalent uniform load table for various spans to produce the same maximum shear and B.M. at the sections noted in the table as a train having axle loads as per Ministry of Transport's standard train.

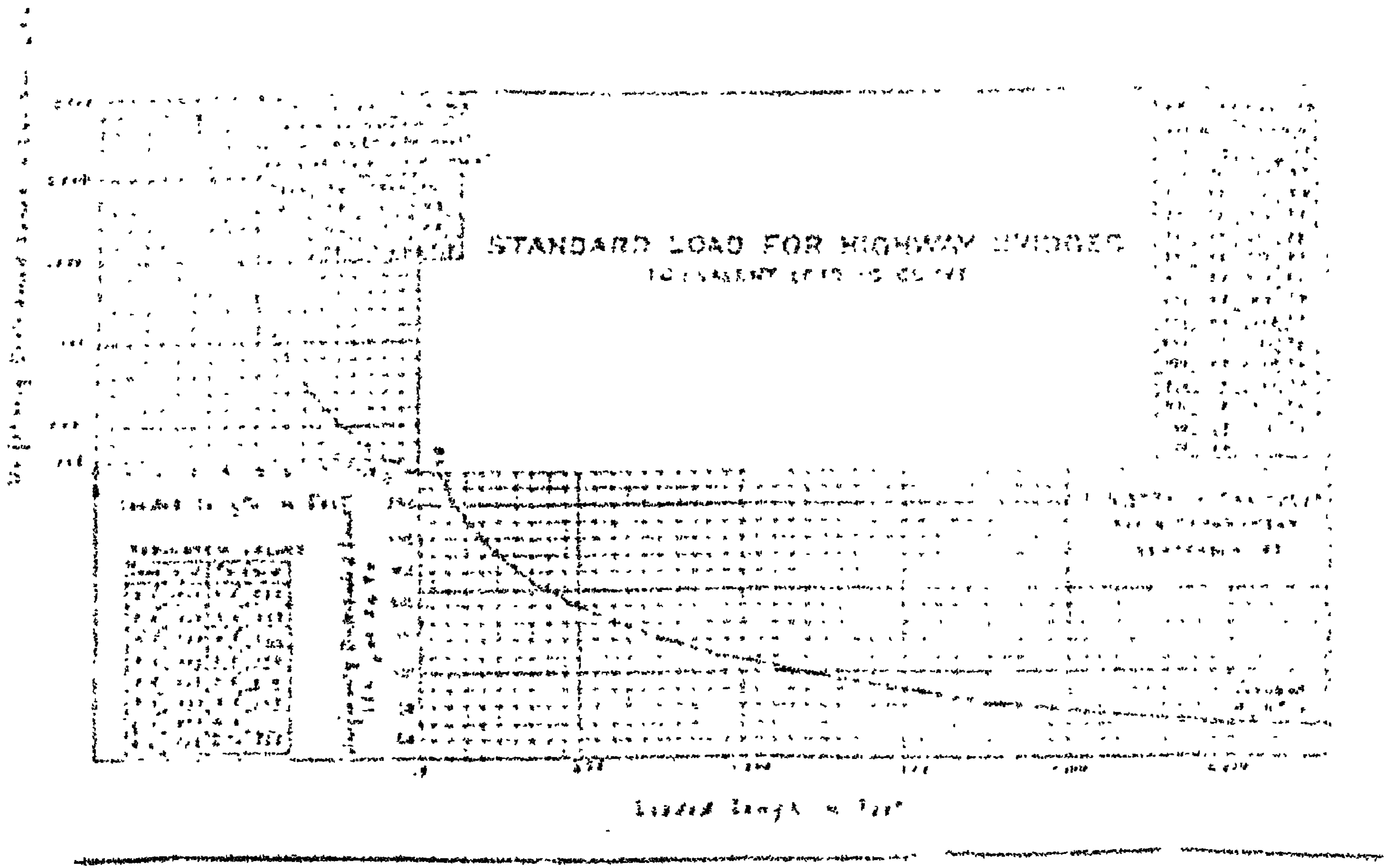
Span in feet.	Maximum shear force at end.	Equivalent load in tons per foot run.	Maximum bending moment at 1/10th span tons feet.	Equivalent uniform load in ton per foot run.	Maximum bending moment at centre of span tons feet.	Equivalent uniform load in tons per foot run.
6	22	7·34	11·88	7·34	33	7·34
8	22	5·50	15·84	5·5	44	5·50
10	22	4·40	19·8	4·4	55	4·40
12	23·3	3·89	24·4	3·77	66	3·66
15	24·6	3·29	32·5	3·21	82·5	2·93
20	26·5	2·65	46	2·56	110	2·20
25	29·2	2·34	63	2·24	150	1·92
30	32·0	2·13	81	2·00	200	1·78
40	37·25	1·86	126	1·75	305	1·53
50	42·8	1·71	179	1·59	455	1·455
60	48·2	1·605	242	1·49	620	1·38
70	53·4	1·53	313	1·42	820	1·34
80	59·5	1·49	394	1·37	1,045	1·31
100	71·9	1·44	593	1·32	1,580	1·26
150	101·1	1·348	1.277	1·26	3,375	1·20
200	131·6	1·315	2,225	1·235	6,080	1·216

Towards the end of 1931, equivalent uniform load curve was introduced to simplify the method of application of the type loading of the

Ministry of Transport for all spans up to 2,500 feet. It includes 50 per cent. impact allowance and is applicable to the design of all bridge members—slabs girder, arches, suspension cables, etc. Equivalent load table for different spans is given below:—

Span.	Pounds per square foot.	Span.	Pounds per square foot.	Span.	Pounds per square foot.
feet. inches.					
3 0 . .	2,420	100	208	1,200	100
3 6 . .	2,020	150	192	1,300	97
4 0 . .	1,700	200	180	1,400	94
4 6 . .	1,445	250	170	1,500	90
5 0 . .	1,225	300	163	1,600	88
5 6 . .	1,033	350	156	1,700	85
6 0 . .	872	400	150	1,800	82
6 6 . .	735	450	145	1,900	79
7 0 . .	625	500	140	2,000	77
7 6 . .	525	600	132	2,100	76
8 0 . .	444	700	125	2,200	74
8 6 . .	374	800	119	2,300	73
9 0 . .	314	900	114	2,400	72
9 6 . .	265	1,000	108	2,500	70
10 0 . .	220	1,100	104	..	..
to 75 0 . .	..	..	..	..	..

The uniformly distributed load applicable to the "loaded length" of the bridge or member in question is selected from the curve or table. (Fig. 4.)


STANDARD LOAD FOR HIGHWAY BRIDGES

* * * * *

The "loaded length" is the length of member loaded in order to produce the most severe stresses. In a freely supported span the "loaded length" would thus be (*a*) for bending moment; the full span. (*b*) for shear at the support; the full span. (*c*) for shear at intermediate point from this point to the farther support.

In arches and continuous spans the "loaded length" can be taken from the influence line curves.

The live load to be used consists of two items. (1) The uniformly distributed load which varies with the loaded length, and which represents the ordinary axle loads of the empty standard train, perfectly distributed (2) An invariable knife edge load of 2,700 pounds per foot of width applied at the section where it will, when combined with the uniformly distributed load, be most effective, *i.e.*, in a freely supported span. (*a*) for bending moment at midspan; at midspan point. (*b*) for shear at the support; at the support. (*c*) for shear at any section; at the section.

This knife edge load represents the excess in the M. T. standard train of the heavy axle over the other axles, this excess being undistributed (except laterally as already assumed).

In spans of less than 10 feet (*i.e.*, less than the axle spacing) the concentration serves to counteract the over-dispersion of the distributed load.

In slabs the knife edge load of 2,700 pounds per foot of width is taken as acting parallel to the supporting members, irrespective of the direction in which the slab spans.

In longitudinal girders, stringer, etc., this concentrated loading is taken as acting transversely to them (*i.e.*, parallel with their supports).

In transverse beams the concentrated loading is taken as acting in line with them (*i.e.*, 2,700 pounds per foot run of beam).

If longitudinal or transverse members are spaced more closely than at 5 foot centres, the live load allocated to them shall be that calculated on a 5 foot wide strip. With wider spacing this strip will be equal to the girder spacing.

In all cases, irrespective of span length, one knife edge load of 2,700 pounds per foot of width is taken as acting in conjunction with the uniformly distributed load appropriate to the span or "loaded length".

* * * * *

In the standard train, the loading is taken as distributed fairly evenly over its full length, if the excess axle load of the back axle of the engine is taken out. The table has been calculated on the assumption that this uniform load is spread over the area under consideration, with the addition of a line or knife edge load equivalent to the excess load of the heavy axle, *i.e.*, 2,700 pounds per foot of width. As this paper is not directly concerned with these details of calculation, I refrain from discussing these points any further. Details can be found in any standard book on bridges. The equivalent loading curve is, however, given (fig. 4) with explanation regarding its application, as given by the Minister of Transport.

(2) British Standard Unit Loading (1925).

The highway girder bridge loadings of the B. E. S. A. of 1925 is very similar to the Ministry's standard train with uniform axle spacing of 10 feet. As the B. S. I. loading is intended to be used all over the world it must be appropriate to widely differing conditions and so the loading is shown on a unit basis and the engineer may adopt as many units of this loading as the local condition necessitates. Addition for impact is to be derived from the following provisional formula (this formula is going to be modified in the near future).

$$I = \frac{87}{90 + \frac{n+1}{2} L};$$

where L=loaded length in feet of the track producing the maximum stress in the bridge member.

n=the number of lines of traffic, which the girder or member is designed to support or assists in supporting.

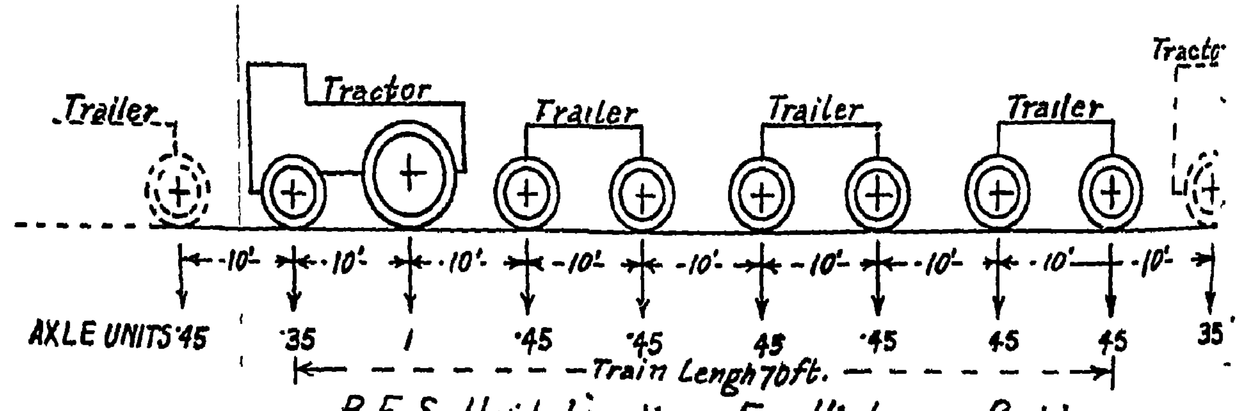
I=coefficient of impact to be multiplied by the live load to give the addition to be made for impact.

The maximum value of the factor I is taken as 0·7 for road bridges.

For pedestrian traffic, a minimum load of 84 pounds per square foot without any impact addition, is suggested.

For footways, Ministry of Transport's standard is 112 pounds per square foot and allowance is to be made, when necessary, for the concentrated load caused by a vehicle mounting on the footway.

As shown before, the Ministry of Transport has adopted a constant impact addition of 50 per cent. for rolling loads. The diagram of B. S. I. unit train loading is shown below:—



B.E.S. Unit Loading For Highway Bridges

Track Front 5'. Outside Rear Wheel 9'. Trailer Track 6' Traffic Lane 10'·0"

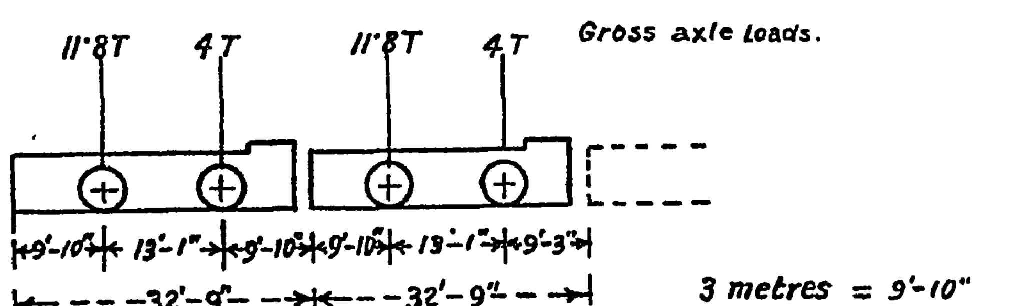
Fig. 5.

In the B. S. I. standard train 35 per cent. of load of the traction engine is assumed to be carried on front axle and 65 per cent on rear axle (which is taken as 1 ton) and each of the trailing axle is to contain 45 per cent. of the back axle load of the traction engine, drawing 3 trailers with uniform 10 foot wheel base. Each 10 foot width of carriage way of the bridge is to be assumed as completely occupied by a succession of standard trains.

If we assume that all the axles carry a uniform load of 0·45 ton and taking the axle spacing as 10 feet and distribution width of load as 10 feet, then the intensity of load per square foot$=\frac{0\cdot45\times2240}{10\times10}$ pounds.

The excess load in the rear or the heaviest axle of the tractor, *i.e.*, (1—0·45) *i.e.*, 0·55 tons may be assumed as a knife edge live load spread over 10 feet width of the road and this is$=\frac{0\cdot55\times2240}{10}$ say 123 pounds per foot width and a load curve for B. E. S. A. unit loading similar to M. T. of loading may be drawn for easy application.

(3) French Loadings—(1928).



FRENCH STANDARD LORRY LOADING
TRACK 5'-6", Tyre 12". LANE 8'-2"

Fig. 6

The loading introduced in France in 1928 for highway bridges on all national roads in modification of the previous official requirements, includes the following:—

A load per square metre, varying with the span as per formula:—

Super load in pounds per square foot$=168-\cdot25\times$length of span in feet. This is to be applied to spans over 65 feet.

Footway live load of 400 kilogrammes per square metre or 82 pounds per square foot.

For the main girders of small bridges up to 65 foot span and for the cross girders of large and small bridges, a loading as shown in the above diagram of "French standard lorry loading" is adopted. The maximum width of a vehicle permitted by the regulations is 2·5 m. or 8·2 feet. That is the above lorry loads are to be taken per 8·2 feet (2·5 metre) lane of traffic. The wheel track of the lorry is taken as 5·6 feet and the width of back wheel is taken as 12 inches. The distance between the backs of two successive lorries in a lane is taken as 32·8 feet=(10 metres).

4 tonne front axle=3·9 tons or load per front wheel=2 tons, say.

12 tonne back axle=11·8 tons or load per back wheel=5·9 tons.

Impact allowance is to be added both to the lorry loads and the uniformly distributed super loads.

(4) (a) U. S. A. Loadings (1923).

The Association of State Highway Officials in "Specification for steel Highway Bridges" adopted in 1923, specifies the following live loads.

A. *Concentrated live loads.*—Class A bridges, *i.e.*, bridges on primary roads with roadway 18 feet wide or more are to be designed for two 15-ton trucks.

Class B bridges, *i.e.*, light traffic bridges, are to be designed for one 15-ton truck.

Class C bridges *i.e.*, heavy traffic bridges for roadway less than 18 feet one 20-ton truck; for bridges over 18 feet two 20-ton trucks. The standard truck is to have axles 14 feet centres, wheels 6 feet centres, 80 per cent. of total load on rear axle, each rear tire to have one inch width for each ton weight of truck.

The Iowa State Highway Commission has adopted the above loading but has added another classification.

Class D.—For unimportant bridges the live load on bridges with a roadway less than 18 feet shall be one 10-ton truck and for bridges with roadway more than 18 feet, one 15-ton truck.

In the western and northwestern states, traction engine weighing 20 tons are quite common. The heaviest motor truck in common use has a capacity of $7\frac{1}{2}$ tons and a gross weight of 13 tons with nearly 80 per cent. of the load, *i.e.*, about 10 tons on the rear axle. Taking 50 per cent. overload which is not unusual, this axle load comes up to 14 tons. The maximum weight of a road roller is 20 tons.

B. *Impact.*—The impact factor is to be calculated by the following formula recommended by the American Association of State Highway Officials in 1923:—

$$I=\frac{L+250}{10L+500}$$

The "American Society of Civil Engineers" in the tentative specifications for steel highway bridges (1923) adopted the following specification for impact on highway bridges.

(*a*) For floor beams and stringers $I=30$ per cent.

(*b*) On floor beams hangers $I=60$ per cent.

(*c*) For girders and trusses $I=\dfrac{100}{L+300}$, where

L = loaded length of span in feet.

C. *Distribution of concentrated Loads.*—In designing floor slabs, floor stringers and floor beams it is necessary to know the distribution of the concentrated wheel loads.

(1) *Concrete floor slabs*—

Ohio tests conclusions are noted below.

(*a*) "The percentage of reinforcement has little or no effect upon the distribution to the joists, so long as safe loads on the slabs are not exceeded.

(*b*) "The outside joists should be designed for the same total live loads as the intermediate joists.

(*c*) "The axle load of a truck may be considered as distributed over 12 feet in width of roadway.

(*d*) "The safe value for "effective width" of a slab where the total width of slab is greater than $1\cdot33L+4$ feet is given by the formula $e=0\cdot6L+1\cdot7$ feet, where e=effective width (*i.e.*, width over which a single concentrated load may be considered as uniformly distributed on a line down the middle of the slab parallel to the supports) and L=span in feet."

The State Highway Department of Ohio uses the following distribution of concentrated loads on floor slabs.

For spans less than 6 feet, the percentage of the wheel load carried by 1 foot width of slab is given by the formula $P=42-4L$; where P=percentage of wheel load and L=span in feet.

For spans greater than 6 feet, the percentage is given by $P'=20-0\cdot4L$.

(2) *Floor stringers and floor beams*—

The 1923 specifications for steel highway bridges of the American Society of S. H. O., American Society of C. E. and of the Iowa Highway Commission contain the following specifications for the distribution of loads to floor stringers and floor beams.

(*a*) *Bending moment in stringers.*—In determining bending moment in stringers each wheel load shall be assumed to be concentrated at a point.

(i) When the floor system is designed for one truck, each interior stringer shall be proportioned to support that part of one rear wheel load or those parts of one front wheel load and one rear wheel load, represented by a fraction, the numerator of which is the stringer spacing in feet, and the denominator of which is 4 feet for plank floor; 5 feet for 4 inch and 6 inch strip floors and wood blocks on a 4 inch plank subfloor, 6 feet for reinforced concrete floor.

(ii) When the floor system is designed for two trucks, the corresponding length shall be 3 feet 6 inches for plank floors, 4 feet for 4 inch and 6 inch strip floors and wood blocks on a 4 inch plank sub-floor, 4 feet 6 inch for a reinforced concrete floor. When the stringer spacing is greater than this distance the stringer loads shall be determined by assuming the flooring between stringers to act as simple beams.

The live load supported by the outside stringers shall in no case be less than would be required for interior stringers.

(b) *Bending moment in floor beams.*—In determining bending moment in floor beams, each wheel load shall be assumed as concentrated at a point. When stringers are omitted and the floor is supported directly on the floor beams, the latter shall be proportioned to carry that fraction of one axle load, when the floor system is designed for two trucks, the numerator of which is the floor beam spacing in feet, and the denominator of which is:—4 feet for plank floors, 5 feet for 4 inch and 6 inch strip floors and wood blocks on a 4 inch plank sub-floor, 6 feet for reinforced concrete floor. When the spacing of floor beams exceeds the denominator given but is less than the axle spacing (14 feet), each beam shall be proportioned to carry the full axle load or loads.

In this place it is necessary to mention that on cross girders, the maximum live load stress will be set up when the heaviest axles are immediately over the cross girder. But where the cross girders are placed close together, portion of the load may be taken as spread over more than one cross girder. In case of B. E. S. A. loading, the wheel base of the engine is taken as 10 feet and for a bridge floor with either of continuous concrete slabs or of steel decking, the proportion of heaviest axle weight on the cross girders may be taken as follows:—

Spacing of cross girders in feet.	Proportion of heaviest axle weight.
3	0·6
4	0·8
5	0·9
6 to 10	1·0
11	1·04
12	1·1
14	1·25
16	1·3
18	1·3
20	1·4

D. *Uniform live loads for girders and trusses.*—The uniform load to be used shall correspond to the length of that portion of the span which when fully loaded will produce maximum stress in the member under consideration.

When the loaded length is less than 50 feet, girder and truss members shall be designed for the floor live load. The trucks shall be placed so as to produce the most large stresses. Two trucks shall be considered as headed in the same direction. Trucks in tandem need not be considered.

Table to show uniform loads for girders and trusses.

Loaded length in feet.	Live load in pounds per square foot (Proportionate values for intermediate length).		
	115-ton truck.	120-ton truck 215-ton trucks.	220-ton trucks.
50	100	130	180
100	80	90	120
200 & more	60	70	90

E. *Floor live loads*.—All parts of the floor system and all girders and truss members when the loaded length is less than 50 feet, shall be designed for the following loads:—

(*a*) one 15-ton truck or 100 lbs./s. ft. of roadway.

(*b*) one 20-ton truck or 130 lbs./s. ft. of roadway.

(*c*) two 15-ton trucks, and

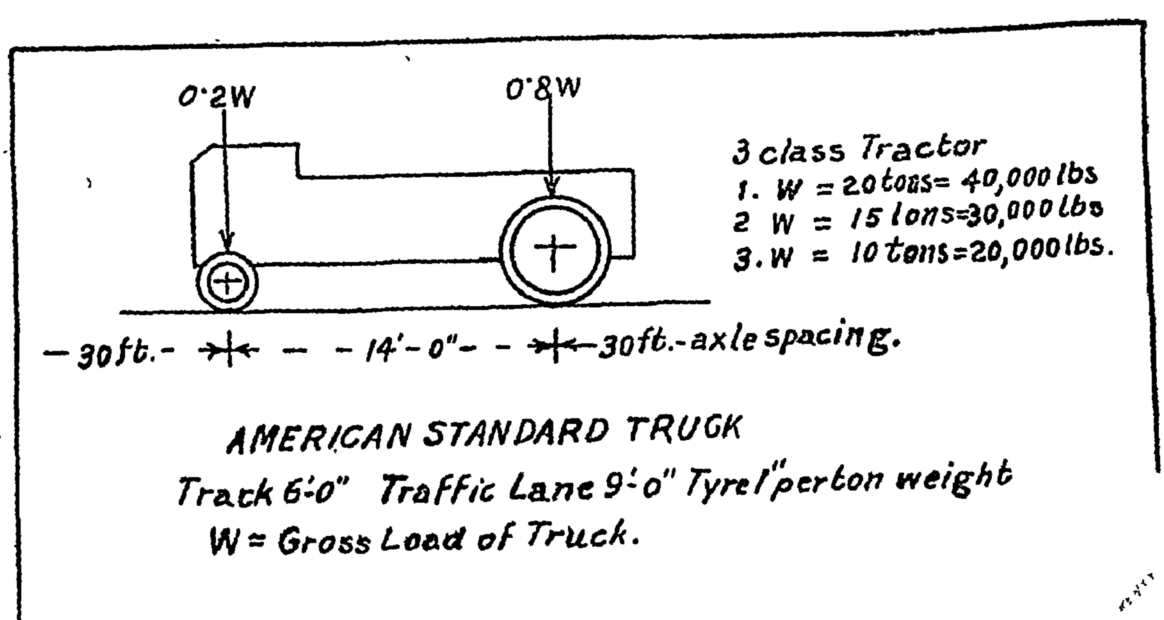
(*d*) two 20-ton trucks.

In bridges involving three or more lines of traffic, the floor beams and floor beam hangers shall be designed for two trucks assumed to be located in the most unfavourable position, together with a uniform live load of 100 pounds per square foot on the remaining lines of roadway not occupied by the trucks.

F. *Side walk live loads*.—Side walk live loads shall be 80 pounds per square foot for loaded length of 50 feet or less and 60 pounds per square foot for 100 feet or more. For intermediate lengths proportionate loads shall be used.

4. (b) U. S. A. Loadings (1931).

Fig. 7.



The U. S. A. loadings given before have now been revised. The specifications for Highway Bridges of the American Association of Highway Officials adopted in 1931, specify the following loadings:—

(A) The following truck train loadings are to be used for loaded lengths up to 60 feet. Necessary impact addition is to be made.

Class of bridge.	Class loading.	Gross weight of truck.
AA	H 20	20 tons = 40,000 pounds.
A	H 15	15 tons = 30,000 „
B	H 10	10 tons = 20,000 „

The train is to be considered as occupying a 9 foot width of traffic lane and consisting of one standard truck of the class specified above followed by an unlimited number of trucks each of gross weight of 75 per cent. of the class truck. The standard truck is to have a 14 foot wheel base and 6 foot wheel track and 80 per cent. of total load on rear axle; each rear tyre to have one inch in width for each ton weight of truck. The distance centre to centre of nearest axles of different trucks is 30 feet (Fig. 7).

Trucks in adjacent lanes are assumed to be headed in the same direction.

(B) *Equivalent loadings.*—The figures for equivalent loadings as given below are to be used for loaded lengths of 60 feet or greater. Impact addition is to be made to these figures. Impact $I = \dfrac{50}{L+125}$, where L = loaded length in feet.

Corresponding to loading.	Uniform load per foot length per 9-foot width lane in pounds.	*Plus* knife edge load placed to set up maximum stress in pounds per 9 foot width or lane.	
		For bending moment.	For shear.
H 20	640	18,000	26,000
H 15	480	13,500	19,500
H 10	320	5,000	13,000

Where the width of the carriage way exceeds a multiple of 9 feet, such excess shall be assumed to be loaded *pro rata*. For bridges with roadway over 18 feet a reduction of uniform load of 1 per cent. for each foot of width in excess of 18 feet with a maximum reduction of 25 per cent. is to be allowed. This maximum reduction of 25 per cent. is reached when the carriage way is 43 feet wide.

(C) *Distribution of concentrated wheel loads,* i.e., *live load*—

(i) *For shear in stringers and floor beams.*—For calculations of shear and end reactions in stringers and floor beams no dispersion of wheel load in either direction is to be taken.

(ii) *For Bending Moments in longitudinal stringers.*—For bending moments (when the floor is of concrete) no longitudinal dispersion of load is to be considered in designing longitudinal stringers and beams. For interior stringers, transverse dispersion is to be allowed for by considering the fraction of a wheel load to each stringer equal to S/6, where S = stringer or beam spacing in feet; for floors designed for one line of traffic with a maximum value for S = 6. For two or more lines of traffic, the fraction should be S/4·5, with a maximum value for S = 10. When the spacings exceed the values mentioned above, the actual wheel loads are to be taken, assuming that the floor slab acts as a simple beam between stringers or beams. Distribution to outside stringers is to be taken directly for the wheel loads, the floor slab being assumed to act as a simple beam.

(iii) *For Bending Moments in cross-beams.*—For cross-beams or transverse floor beams, when longitudinal stringers are omitted, no dispersion of load along the beam is to be taken.

The proportion of wheel load to be distributed to the beams = S/6, where S = spacing of beam in feet, the maximum value of S should be taken as 6. Where S exceeds 6 feet the actual wheel loads are to be taken, it being assumed that the floor slab acts as a simple beam between the members.

(iv) *Wheel loads on floor slabs.*—Dispersion of wheel is not to be assumed in the direction of the span of the slab.

(*a*) For lateral dispersion, the "effective width" of the slab (for one wheel) is to be calculated by the formula $E = 0{\cdot}7\,S + W$, where W = tire width and S = span of slab in feet, when the slab spans in the direction of traffic. The maximum value of "E" is to be taken as 7 feet when two wheels of adjacent vehicles are placed side by side, so that the effective widths overlap, the effective width of each wheel becomes $\frac{1}{2}(E+C)$ where E is determined as above and C is the distance between centre to centre of wheels.

(*b*) When the slabs are spaced transversely to the traffic line, the effective width $E = 0{\cdot}7\,(2D+W)$ where D = distance in feet from the centre of the wheel to the centre of the nearer support. Slabs which are designed for these bending moments are assumed to be strong enough for shear. The methods of calculation described here do not hold good, where the edges of slabs are not supported. In such cases special provision is to be made to carry the wheel load concentration.

(D) *Side walk and foot bridge loading*—

(*a*) For local design, *i.e.*, for design of floors, stringers and immediate supports, a uniformly distributed live load of less than 100 lbs. per square foot should be used.

(*b*) For design of trusses and girders for foot bridges or side walks.

Loads for trusses and girders are to be calculated from the formula:

$$P = \left(40 + \frac{3000}{L}\right)\left(\frac{55 - W}{50}\right),$$

where P = live load in pounds per square foot (not to exceed 100).
L = loaded length in feet.
W = width of side walk in feet.

(5) Canadian Specifications for Loadings.

The Canadian standard specification 1929 for highway bridges prescribed the following loadings.

1. *Loadings.*—Bridges are to be designed for various combinations of vehicle loads and uniform loads as follows:

(*a*) *Vehicle loads.*—These are to be selected by the engineers from one of the following classes. Trucks are assumed to occupy a 9-foot lane.

(1) 20-ton truck with 80 per cent. load on rear axle.

One back wheel load = 8 tons at 2,000 pounds =	16,000	pounds.
plus 30 per cent. impact =	4,800	,,
Total	20,800	,,

(2) 15-ton truck with 80 per cent. load on rear axle.

One back wheel load = 6 tons at 2,000 pounds =	12,000	pounds.
plus 30 per cent. impact =	3,600	,,
Total	15,600	,,

(3) 10-ton truck with 80 per cent. load on rear axle.

One back wheel load = 4 tons at 2,000 pounds =	8,000	pounds.
plus 30 per cent. impact =	2,400	,,
Total	10,400	,,

Provision for electric cars are to be made where necessary and the following loads are recommended. The cars classified into three classes, each consisting of two trucks occupying a 10 foot lane of traffic.

(i) Axle concentration—25,000 pounds spaced 5 feet, 20 feet, 5 feet, 10 feet, 5 feet, 20 feet and 15 feet.

(ii) Axle concentration—2,000 pounds spaced as above.

(iii) Axle concentration—15,000 pounds spaced as above.

(*b*) Uniformly distributed loads.

These are as shown in the table and are to be selected from one of the following classes:—

Class.	Spans of 100 feet or less.	Spans of 200 feet or more.
In pounds per Square foot.		
U—100	100	80
U—80	80	60
U—70	70	50

Proportionate values for spans intermediate between 100 and 200 are to be taken. No impact is to be added to this loading.

2. *Impact.*—An increase of 30 per cent. is to be made to wheel load stresses but no increase is to be made for the uniformly distributed load.

(6) Standard Loadings for Road Bridges in India.

The Committee of Chief Engineers made their recommendations about standard loadings for road bridges in India which were accepted by the Road Conference in September, 1931. Extracts are given below.

PROCEEDINGS OF THE ROAD CONFERENCE AND ITS COMMITTEE HELD IN SIMLA, 21ST TO 28TH SEPTEMBER, 1931.

Copy of the report to the Road Conference of the Committee of Chief Engineers on September 23rd, 1931.

"6. We have carefully considered whether it is possible to lay down any standard loading to which bridges in India should be designed. We consider that for this purpose roads may be divided into three classes :—

(*a*) special localities such as industrial areas where unusally heavy loads may be expected.

(*b*) the general case of all roads, with the exception of the above which at present carry, or may in course of time be expected to carry, motor transport.

(*c*) roads which, owing to the locality, grading, etc., can never be expected to carry motor traffic.

As regards class (*a*), we consider that the designes of bridges of such localities cannot be standardized, but that local considerations must decide the provision to be made.

With regard to class (*b*), we consider that it is desirable to lay down a minimum strength. We have been impressed on the one hand by a desire to avoid undue extravagance in the provision of unnecessarily strong bridges and on the other by a desire to avoid waste by specifying the construction of bridges which may before long prove to be too weak for traffic and have to be reconstructed. We do not consider that it is necessary or possible to differentiate between various classes of roads further than we have done, and we recommend in the case of class (*b*) firstly that bridges should be designed on the basis of 10 foot lanes, and we propose to consider the general case of the 2 lane bridge with a clear width of 20 feet. This, we consider incidentally, should be the general standard for trunk roads away from towns where wider bridges are called for. For this class of bridge we recommend that the standard should be 12 British Engineering Standards Association units for all spans up to 100

feet and that for spans between 100 and 300 feet a sliding scale from 12 down to 8 units should be adopted. Mr. Ayyanger considers that 15 B. E. S. A. units should be adopted in view of the fact that no allowance is made for impact and also of the comparative difficulty of strengthening bridges once constructed. We do not consider it necessary for main girders, etc., to make any additional allowance for impact. This recommendation is, we consider, sufficient for the general case and economical. It is in fact more than the loading to which many road bridges in India have heretofore been designed.

In respect of bridges on class (*c*) roads, which will include bridge paths, pack *traffic roads, etc., we do not consider that there is any necessity for an all India* standard.

The Committee then turned to item 8 of the agenda, that is the question of standard recommendations regarding tyres, loads and speeds for motor vehicles of various classes. The Committee generally approved of the recommendations made by the Road Engineer with the Government of India, *vide* Appendix V. C. E. with the following provisos.

(*a*) Solid tyres less than an inch in thickness from the rim or solid tyres which are badly cut or broken should be prohibited.

(*b*) The Committee specially endorsed the recommendations regarding the width of solid rubber tyres.

(c) The Committee endorsed the recommendations regarding speed limits to be imposed in various cases, subject to the conversion of the schedule into terms of laden weight or possibly unladen weight whichever might be most convenient from the point of view of the model rules as a whole."

The Committee then turned to item 9 of the Agenda, that is to say the standard bridge loading and accepted the recommendations of the Committee of Chief Engineers.

EXTRACTS FROM APPENDIX V. C. E.

NOTE ON THE REGULATIONS REGARDING THE TYRES AND SPEEDS OF MOTOR VEHICLES NECESSARY FOR THE PROTECTION OF ROADS IN INDIA.

Speeds.

(*a*) Lorries (and buses if so allowed) with solid tyres—(proposed speed)—

up to 3½ tons axle load—15 miles per hour.

up to 5 tons axle load—10 miles per hour.

over 5 tons axle load—solid tyres prohibited

(*b*) Lorries and buses with pneumatic tyres—(proposed speed)—

up to 1½ tons axle load—30 miles per hour.

up to 2½ tons axle load—25 miles per hour

up to 3½ tons axle load—20 miles per hour.

up to 4½ tons axle load—15 miles per hour.

Over 4½ tons axle load—10 miles per hour.

Tyres.

Solid tyres.—Minimum nominal width—4 inches and a limit of 400 pounds per inch width. On a 2½ ton lorry with an axle load of about 3½ ton the width required would be—

American proposal single tyre—6 inches wide.

Australian proposal single tyre—8 inches wide

Our proposal single tyre—10 inches wide

Pneumatic tyres.—The use of balloon tyres is to be prohibited.

(7) *In the "Military Engineer Services Handbook"* (1925 edition, reprinted in 1930) certain recommendations are made for the standard loading for road bridges on roads of military importance, which are subjected to carry mechanical transport and also for cart roads in India. Extracts are given below.

(a) *Live loads.*—"The live load for design should be based on the maximum probable loading in relation to the span and not on the maximum possible. For exceptional cases, it is permissible to increase the stress by 25 to 30 per cent. As the span increases the probability of heavy loading over the whole span decreases"

(b) Impact load is calculated by the formula.

$$\text{Impact load} = \text{live load} \times \frac{300 \times}{nL+300}$$

where $x = 1$ for steam rail roads,

$= \frac{1}{2}$ for electric cars,

$= 1/3$ for motor lorries, etc.

$= \frac{1}{4}$ for road rollers, crowds and cattle.

n = number of railway tracks or $\frac{\text{width of road in ft.}}{20}$ for roads,

L = loaded length of the span in feet.

At speeds less than 5 to 10 miles per hour there is practically no impact hence when dealing with exceptional loads due to crowded vehicles, people or animals, no impact need be allowed.

(c) *Loads for design of floor system.*—The decking or flooring system should be designed to allow for one 12 ton road roller *plus* 25 per cent. impact, for the following dimensions and weights—

(1) Wheel base—10 feet.
(2) Track of roller—5 feet.
(3) Width of back roller—1·32 feet.
(4) Load including impact on front axle=6·87 tons=15,400 pounds,
(5) Load on rear axle with 25 per cent. impact=10 tons=22,400 pounds.

For distribution of concentrated loads in calculating stresses in slabs, stringers and floor beams, the American method is adopted.

For design of main girders, trusses and arch rings or ribs, the following uniformly distributed loads are recommended. These loads includes impact allowance.

Table of uniform live loads for different spans.

Span in feet.	For girders and trusses Pounds per square foot.	For arch rings or ribs Pounds per square foot.	Span in feet.	For girders and trusses Pounds per square foot.	For arch rings or ribs Pounds per square foot.
10	450	450	70	115	160
15	300	420	80	110	155
20	240	340	90	105	145
25	210	300	100	100	140
30	190	270	120	95	130
35	170	240	140	90	125
40	150	210	160	85	120
45	140	190	180	80	110
50	130	180	200	75	105
60	120	170	Over 200	70	100

For intermediate spans loads should be proportionately interpolated. The loads given for arches are about 40 per cent. greater than for trusses as partial loading gives the maximum stresses.

Wind loads for trusses.—Wind loads on trusses should be taken as follows :—

(i) A horizontal load on the loaded chord of 300 pounds per lineal foot.

(ii) A horizontal load on the unloaded chord of 150 pounds per lineal foot capacity of bridges so designed :—

The bridges designed for the concentrated load of 12 ton road roller and also for the uniform loads as given in the table, will safely carry the traffic detained below.

Normal.

1. Two 12-ton road rollers abreast or in a file at 30 foot clear intervals.
2. 15 ton caterpillar tractors at 30 foot clear intervals.
3. A double line of 3-ton motor lorries at a check (8 tons loaded).
4. All marching formations of cavalry, field artillery, infantry, camel, mule and army transport, passing similar formations on the bridge.
5. All crowds of pedestrians and cattle, pack animals and carts.
6. Any train of loads in which no axle load exceeds 8 tons nor caterpillar axle load 12 tons and in which the load per square foot

$$W=\frac{\text{total load in lbs}\times 1\cdot 25\text{ for impact}}{10\text{ ft.}\times(\text{length of train}+10\text{ ft.})}$$

does not exceed that given in the table for a span equal to the length of the train *plus* 10 feet.

Emergency.

Bridges designed as above will also take the following loads at safe stresses with restrictions *i.e.*, speed 4 miles per hour, load on centre of road and no other load along side :—

1. 18 ton whippet tanks at 25 foot clear intervals.
2. 16 ton wheel tractors at 25 foot clear intervals.
3. 8 inch Howitzer hauled by 11 ton caterpillar, subject to the floor stress being increased by 5 per cent.
4. 6 inch B. L. gun, Mark VII hauled by 16 ton tractor, subject to the floor stress being increased by 25 per cent.
5. 12 inch Howitzer, hauled in two trains by 14 ton caterpillars; trains at 60 feet clear interval.
6. 9·2 inch Howitzer hauled by 11 ton caterpillar.
7. 6 inch Gun mark XIX hauled by 11 ton caterpillar.
8. Any train of loads in which no axle load exceeds 12 tons, nor caterpillar axle loads 18 tons and in which the load per square foot.

$$W=\frac{\text{total load in pounds}}{\text{width of road}\times(\text{length of train}+10\text{ feet})},$$

does not exceed that given in the table of uniform loads for a span equal to the length of the train *plus* 10 feet.

These bridges will not take 30 ton tanks.

Bridges on pack transport roads.

For bridges on pack transport roads, the following loads have been recommended for the design of floors, beams, girders and trusses.

Span in ft.	1	5	10	15	20	25	30	35	40	45	50	60	80	100 and over
Load in lbs./sft. .	150	140	130	120	110	100	90	80	75	70	65	60	55	50

For intermediate spans proportionate loads should be interpolated.

SUGGESTED STANDARD LOADINGS FOR BRIDGES IN INDIA.

55. I have shown before that an important change in road requirements has taken place during recent years owing to the rapid growth and ever increasing popularity of mechanical transport by road. Not only has the volume and speed of road traffic increased during recent years but the unit loads now being carried by these vehicles are much heavier than

they were before. This has brought to the forefront not only the necessity of widening, strengthening or reconstruction of many of the old bridges which are now considered quite inadequate to meet the modern heavy and fast traffic conditions but also focussed our attention on the bridging of a large number of major and minor river crossings which exist not only on country roads all over the land but on important trunk and main roads as well. For continuous and through road traffic, these barriers and obstacles are to be removed with the utmost expedition and the urgency of the demand is conceded by all. As remodelling of old bridges and construction of new ones involve a large capital cost, utmost care is to be taken in making the most suitable designs and to adopt that type of bridge which should combine efficiency with the greatest economy. We should neither be extravagant nor should we cut the design too fine, depending only on the existing condition of traffic in the locality, thus making the structure too weak to bear its future expansion. The first consideration of the engineer in designing a bridge is that it shall safely carry the traffic for which it was designed for the largest possible period and at the least possible cost both in construction and upkeep. This provides no doubt a very serious problem for the Highway Engineer.

56. Of late the attention of engineers has been particularly directed to the increased use of reinforced concrete in all sorts of constructions and there are many obvious reasons for the increased popularity of this type of construction, the foremost of which is the entire elimination of upkeep cost of the structures built of this material. Now-a-days owing to the manufacture of high class Portland cement the permissible compressive stress in concrete has been increased. This has effected a substantial reduction in the dead weight of the bridges. The Ministry of Transport now allows a safe compressive stress of 750 pounds per square inch on the concrete and taking 16,000 pounds per square inch as the working tensile stress in steel, the economic percentage of steel will be 0·97 against 0·67 of the old days, when stress in concrete was taken at 600 pounds per square inch. The resisting moment of a section will now be equal to 133·5bd2 against 95bd2 of the old days, where b=breadth and d=effective depth in inches. At the time of design it should be remembered that the strength of reinforced concrete structures increases with age. A concrete which has crushing strength of 3,407 pounds per square inch, after a month, has given 3,761 pounds per square inch after 3 months and 5,129 pounds per square inch after 12 months. Stresses in steel have also been increased from 16,000 pounds to 18,000 pounds per square inch for longitudinal bars in beams, slabs or columns subject to bending.

57. These particularly favourable factors have brought about the increased use of reinforced concrete in bridge building all over the world. The cost of concrete bridges up to 100 foot span compares favourably with that of steel bridges. There are at present 12 (11 in actual operation and one under construction) widely distributed Portland cement factories in India (excluding Burma) turning out high class Portland cement. All the brands of cement which are now being manufactured in India are superior to what is required by the latest (1931) B. E. S. A. specification for Portland cement. The following figures of cement consumption illustrate the growth of the industry during recent years and there is no doubt that India has become cement-minded now.

Total consumption of cement.

Year.	Imported cement in tons.	Cement manufactured in India in tons.	Total consumption in tons.
1914	1,50,530	945	1,51,475
1918	20,016	84,344	1,04,360
1922	1,09,924	1,51,336	2,61,260
1927	69,009	4,77,742	5,46,742
1928	74,700	5,57,953	6,32,653
1929	74,800	5,60,682	6,35,482
1930	68,000	5,64,984	6,32,984
1931	62,500	5,92,600	6,55,100
1932	59,000	5,90,057	6,49,057
1933	42,307	6,25,874	6,68,181
1934	51,800	7,42,950	7,94,750

58. At present there is no dearth of either experienced engineer or workmen, skilled in fero-concrete construction. The recognised working compressive stresses in concrete in road bridge design have now been revised by the Ministry of Transport as noted in the table below. These are applicable both to ordinary or rapid hardening Portland cement.

Concrete mix cement (lb.) Fine aggregate (C. ft.), coarse aggregate (C. ft.).			Working stress (fc.) in pound per square inch, *i.e.*, in flexture.	Modular ratio (n).	Crushing strength of concrete in 6 inch cubes in pounds per square inch.	
					At 28 days with ordinary cement. At 7 days with rapid hardening cement.	An additional test (if required) as an indication at 7 days with ordinary and 3 days with R. H cement should give results as below.
lbs. A	C. ft. 2	C. ft. 4 . .	5A+300	..	15A+900	10A+600
90	2	4 . .	750	15	2,250	1,500
120	2	4 . .	900	15	2,700	1,800
150	2	4 . .	1,050	12	3,150	2'100
180	2	4 . .	1,200	10	3,600	2,400

The crushing strengths of concrete made with different proportion of cement of British manufacture and with stone aggregate and sand (fine aggregate) as found in Great Britain are to be seen in column (3) of the above table. Of course higher strengths have been found but the minimum strengths are laid down as above. It would be surprising to note that crushing strength of cement concrete of 1:2:4 mix. (or 90 pounds: 2 cubic feet: 4 cubic feet) with trap stone aggregate has been found to be 6,000 pounds per square inch at 21 days in Calcutta which is almost double the strength of 150:2:4 mix. cement concrete made in Great Britain at 28 days. Tests were carried out in Alipore Test House on concrete blocks with the following results.

lbs. 90, c. ft. 2, c. ft. 4 mix.	Crushing load on 6″ × 6″ × 6″ block.	Average crushing strength in lbs./sq. inch.	Concrete strength in America lbs./sq. inch.
Gravel concrete . .	1·78 tons per sq. in.	3,685	2,612 to 2,085.
	1·66 „ „		
	1·51 „ „		
	1·645 tons per sq. in. average.		
Jhama brick concrete .	1·19 tons per sq. in.		
	0·94 „ „		
	1·12 „ „		
	1·065 tons per sq. in. average.	2,386	

59. Such higher strength of concrete in this country may be due both to high class of Indian Portland cement and also to the climatic effect of this country. It is now incumbent upon the engineers to investigate this matter and to make use of this higher strength by allowing greater permissible stress in concrete than what has hitherto been done and been recommended by engineers of other countries. This will further reduce cost of construction and will also reduce the dead weight of structures appreciably. The maximum possible span of reinforced concrete girder or beam bridge depends above all on the permissible stress in the concrete so that improvement in quality of cement and specially in its resistance to bending in the tensile zone is of very great importance for the further development of this type of structure.

60. The design data as given below are based on the increased stresses now adopted by the Ministry of Transport. The last one is the old data.

Tensile stress in steel may be taken as 18,000 pounds/square inch in longitudinal bars in beams, slabs, columns subjected to bending.

Tensile stress in steel fs.	Working stresses in concrete fc.	Ratio of depth of neutral axis "R"	Lever arm ratio 1—R/3	Resisting moment Mr	Area of steel AS/bd.
					Per cent.
16,000	0	0·41	0·86	134 bd²	·97
Do.	900	0·46	0·85	175 bd²	1·30
Do.	1050	0·44	0·85	198 bd²	1·44
Do.	1200	0·43	0·86	220 bd²	1·61
Do.	600	0·358	0·88	95 bd²	0·675

Shear stress in concrete may be taken as 75 pounds per square inch and bond stress 100 pounds per square inch.

61. The heaviest commercial vehicles over 5 tons which are at present operating in the different industrial centres of India are as noted below:—

The Calcutta Corporation maintain a big fleet of lorries both for light and heavy transport. The fleet is composed of 34 5-ton lorries, 13 3-ton lorries, six 5-ton tractors, six articulated six wheelers (1-ton Ford truck and 3-ton trailer), 48 1½-ton trucks. (38 Ford and 10 Dodge) eleven 1-ton Ford trucks. There were 18 more trucks which have now been handed over to Garden Reach Municipality now separated from the Calcutta Corporation. There are no lorries of over 5 tons load carrying capacity belonging to Calcutta Corporation.

Place.	Description of vehicle.	Weight unladen.	Weight laden (gross weight).	Remarks.
		T. C. Q.	T. C. Q.	
Calcutta . .	6/7 ton Leyland S. Q. 2.	5 18 0	11 13 0	One only.
Bombay . .	Albion 4 wheeler motor bus to carry 36 passengers.	6 1 2	8 4 1	
	6-ton Leyland T. Q. I (Buffalo).	5 15 0	11 2 0	One only.
	Scammel 6 wheeler	7 12 0	15 18	One only.
Allahabad . .	Fodden steam wagon	4 to 6 tons.	8 to 12 tons.	2 Trailers of 5/6 ton capacity on solid tyres.
Ahmedabad, Patna Lahore, Cawnpore.	No heavy motor vehicle over 5 tons ply in these cities.	..	..	
Burma and Assam	6-ton Leyland T. E. (Terrier) 6 wheeler.	8 0 0	11 13 0	5 in Burma. 1 in Assam.

Tatanagar is another industrial town but the heavy traffic is confined to rail roads and only light cars and lorries ply on the roads in and around the town.

Heavy motor vehicle regulations, in tabular form.

(For details *vide* extracts of rules given in Part III.)

Description of items.	Madras.	Bengal.	Calcutta and Howrah.	Bihar and Orissa.	Punjab.	United Provinces.	Bombay.	British Road Tr. Act, 1930.	Remarks.
1. Gross load of a 4 wheeler (ton).	12	12	12	7½	(1) 12 to 16	(1) 12 to 16	(2) 14	(b) 20½ 12(a)	
2. Gross load of a 6 wheeler (ton).	...	...	16	...	...	...	...	19(c)	
3. Gross load of a 8 wheeler (ton).	...	...	...	...	...	...	...	22(e) limit.	
4. Maximum axle load for 4 wheeler (ton).	8	8 (a)	8	5	8	8	8	8	
5. Maximum axle load for 6 wheeler (ton).	...	...	12	...	...	...	...	7½	
6. Maximum axle load for 8 wheeler (ton).	...	...	...	...	...	...	...	7½	
7. Maximum length of a 4 wheeler.	...	...	27'6"	28'0"	...	...	...	27'6"	
8. Maximum length of a 6 wheeler (rigid).	...	...	30'0"	30'0"	...	...	...	30'0"	
9. Maximum length of a 6 wheeler (articulated).	...	...	33'0"	...	...	...	...	33'0"	
10. Maximum length of a 8 wheeler (rigid).	...	...	...	...	...	...	...	30'0"	
11. Maximum length of a 8 wheeler (articulated).	...	...	...	...	...	...	...	36'0"	
12. Maximum width of a vehicle.	7'6"	...	7'6"	7'6"	7'6"	7'6"	7'6" 8'6"	7'6" 9'0" (b)	
13. Maximum length of coupling of a trailer.	...	...	4'0"	...	...	...	...	... (b)	
14. Maximum number of trailers hauled by a vehicle (4 wheeler).	3	1	1	2	3	3	3	3,	
15. Maximum length of a trailer.	...	...	14'0"	...	...	...	...	22'0"	
16. Maximum length of a train.	36'0"	...	...	75'0"	75'0"	75'0"	30'0" 75'0"	... (a)	
17 Maximum axle weight of a trailer (ton).	4 ton	4	4	5	3	3	4	6½ (d)	
18. Speed limit in m.p.h. according to vehicle weight, etc. (*vide* rules)	5 to 12	8 to 15	8 to 15	8	5 to 12	...	8 to 12	5 to 12	

(1) For vehicles of local authority only.
(2) Applicable to traction engine with trailers.
(a) For articulated vehicle 8 tons. Sum of all axle weights of the vehicle and trailers is 22 tons (maximum).
(b) For road locomotive, maximum gross weight is 20½ ton. 3 trailers locomotives only. One laden trailer for motor car or tractor.
(c) Maximum gross weight of a vehicle of more than 6 wheels 22 tons.
(d) For heavy motor car with trailer. Speed is 5 mile per hour, if equipped with pneumatic tyres, the maximum legal speed is 16 miles per hour. For heavy motor car without trailer 5 to 20 miles per hour.
(e) The maximum total weight of all the trailers drawn by a locomotive not to exceed 40 tons. Axle weight of a heavy motor car propelled by steam is limited to 9 tons.

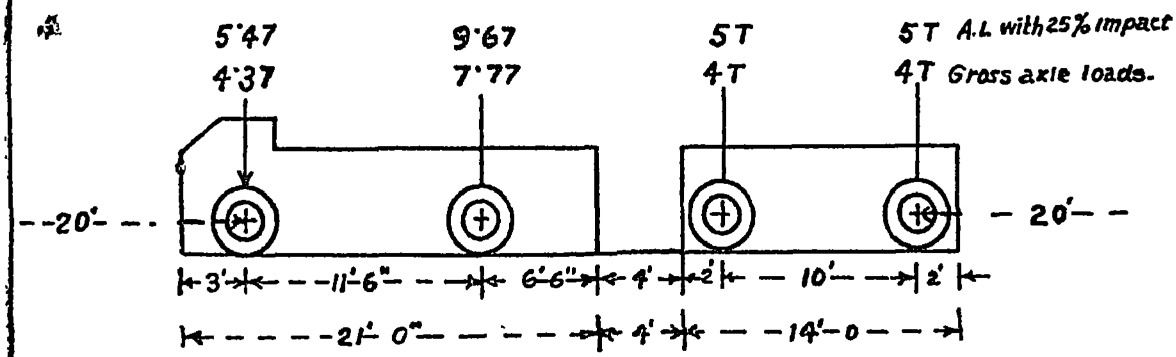
62. The rules regulating the use of motor vehicles in the different provinces of India are not alike and it is high time now that these rules should be standardised as far as possible. Now from these rules it will be seen (*vide* table prepage) that in none of the provinces, a heavy motor car with axle loads more than 8 tons is allowed to run. In the rules of some provinces a train consisting of a tractor hauling 3 trailers with a total length not exceeding 75 feet is also allowed. But such a road train is neither realised in actual practice anywhere in this country at present nor will it be ever realised. There are also very few (if any at all) traction engines with more than 8 tons axle-weights in actual operation in this country, with the exception of road rollers. There is at present one Fodden road locomotive in operation at Allahabad, propelled by steam and drawing 2 trailers. The Corporation of Calcutta owns 53 steam and 3 Diesel engined oil driven road rollers. Out of these, 26 are of 10 tons nominal weights, 11 are of 8 tons, 13 are of 6 tons and 7 are of tandem type.

63. From the statement of road rollers it will be seen that the heaviest compound type of 10 tons road rollers (Marshall's) actually weighs 14 tons and 3 cwts. in working trim and this weight is almost equal to that of John Fowler's 12-ton compound steam roller. The weight on front roller is 4 tons 14 cwts. and that on the back rollers is 9 tons 9 cwts., *i.e.*, 33 per cent. of the total weight is on front rollers and 67 per cent. on the back rollers. The maximum legal axle loads for heavy motor car are confined to 8 tons and the speed is limited to 5 to 12 miles per hour. In Calcutta only 12 ton axle loads on the two back axles of a rigid six wheeler is allowed. The minimum distance between centre to centre of these two axles is 4 feet. At the Road Conference held in Simla in September, 1931, it was proposed to limit the speed for a solid tyred motor vehicle up to 5 ton axle weight to 10 miles per hour (no solid tyre to be allowed on vehicles over 5 tons axle-weight) and for a vehicle with pneumatic tyres and axle weights over 4½ tons to 10 miles an hour. The maximum axle loads for a trailer have been fixed in some provinces at 3 tons and in some at 4 tons. Bihar and Orissa have allowed 5 tons axle loads in the rules. In Calcutta, not more than one trailer is allowed to be hauled by a motor vehicle and the rules do not permit a vehicle with more than 4 wheels and of length not exceeding 26 feet to draw a trailer.

64. It is a point to be considered if heavy steam tractors hauling trailers with such a low speed restriction will ever find favour in India, for the transport of merchandise. Moreover with the introduction of rigid and articulated 6 or 8 wheeler motor vehicles, the load on a single axle is reduced and the modern tendency of motor manufacturers is to reduce axle loads and to increase gross loads for vehicles intended for heavy transports. At present there are few motor vehicles in India of capacity of over 5 tons or gross load of over 10 tons (front axle load 3½ tons and back axle load 6½ tons). From the statement of heaviest vehicles, which are at present running in the main industrial centres of the country, it will be seen that Bombay alone has got one Scammel 6 wheeler of gross load of about 16 tons. Allahabad has one Fodden steam tractor of gross load of about 12 tons, hauling 2 trailers of gross load of 6 tons each. There are at present 5 Leyland vehicles of gross loads of 12 tons each in Burma, one in Assam and one in Calcutta but they are all six wheelers. Taking 12 tons as the maximum gross load of a 4-wheeler that is expected to run in this country in industrial centres only and distributing the load as 35 per cent. on the front axle and 65 per cent. on the back axle and allowing for 50 per cent overload on the pay-load, *i.e.*, about 3 tons, the gross load of a vehicle works out to 15 tons but the legal total axle loads for a four wheeler are restricted to 12 tons only.

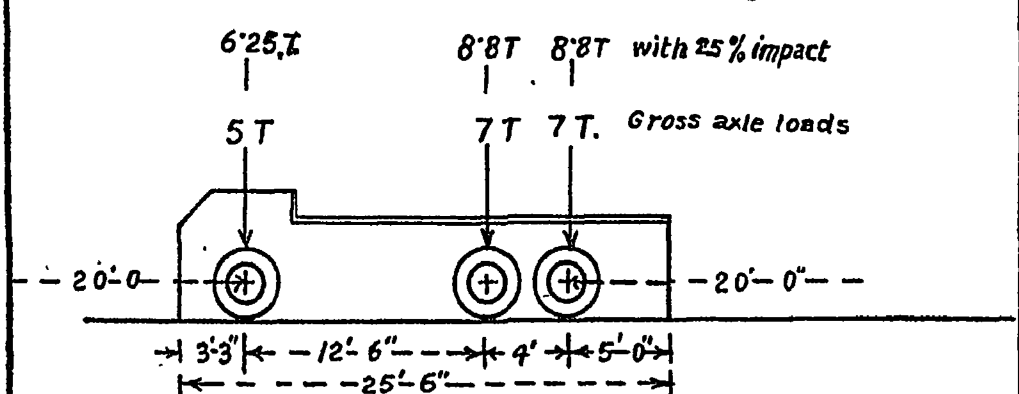
65. For trailers the maximum axle load is limited to 5 tons in one province only (Bihar and Orissa) but it is doubtful whether such a trailer is actually being used anywhere in that province. The maximum length of a trailer is limited to 14 feet in Calcutta. Road rollers of over 10 tons nominal weight are seldom required in road construction work and are also unnecessary. Taking into consideration the S/4 model of Sentinel 4 wheeler hauling a 6 ton trailer the load to be carried by the wagon would be about 7 tons on the wagon and 6 to 7 tons on the trailer and the load distribution would be 4 tons 6 cwts. on the front axle and 7 tons 14 cwts. on the back axle of the vehicles and 4 tons on each axle of the trailer. This weight does not exceed the legal weights and is within the local restrictions. The diagram of such a combination is shown in fig. 8,

taking the smallest overall length of this type of wagon and smallest wheel base 11 feet 6 inches (the length of this type of vehicle varies between 21 feet and 25 feet and the wheel base 11 feet 6 inches and 14 feet 6 inches approximately). The speed limit for such a combination is restricted to 8 miles per hour.



6/7 ton SENTINEL *Wagon & 6/7 Ton Trailer.*
Track 5'-8". Tyre 8" twin. LANE *10'-0"*
Fig. 8

The diagram for a Fodden Tractor (4·25 tons on front axle and 8·25 tons on back axle) drawing 2 trailers would be similar to the above but with 14 feet 9 inches wheel base for the engine with 23 feet as its overall length and one more trailer added to it. The diagram of Sentinel 12 to 15 tons 6-wheeler is given in fig. 9.



12/15 TON SENTINEL 6-WHEELER.
Track 5'-8". Tyre 8" Twin. LANE 10'-0"
Fig. 9

66. According to the existing rules, the maximum gross legal weight of a 6-wheeler is 16 tons and that of a 4-wheeler is 12 tons and there are at present no rules regulating the use of 8-wheelers in any of the provinces of India. Bombay's maximum gross legal weight for a traction engine is 14 tons and the back axle load for such an engine would be about 9 tons. In Bombay one Scammel 6 wheeler is at present in operation. The maximum axle-load of Leyland's heaviest model 6-wheeler (Hippo) is 6 tons 18 cwts. and that of the "Octopus" 8-wheeler is $7\frac{1}{2}$ tons but the load concentration in this case is rather heavy as the centres of two axles are only 4 feet 6 inches apart. So when one of the back axles will be directly over a cross-girder, a portion of the weight of the other axle will also come upon it and that has to be accounted for in designing the member. Stringers will have to bear similar excess stress. However, as the gross load is in excess of the local restrictions, such heavy vehicles cannot run at present on any roads of the country.

67. Now when a heavy vehicle drawing a trailer will be crossing a bridge it is not probable that another similar heavy vehicle will follow it close behind and we can safely allow a margin of at least 20 feet as the distance between centre to centre of nearest axles of different trucks. Taking this as the minimum distance between successive vehicles, a bridge up to 60 feet span will only have one such unit on it at a time on a traffic lane. For spans up to 100 feet there will be two such units and for spans up to 120 feet there will be 3 such units and so on.

68. I had occasion to design and construct several bridges of various lengths and of span generally between 20 to 35 feet, in one of the industrial centres of India, *i.e.*, the Jherria coal field area, some 12 years ago. These were designed to carry 8 ton steam road rollers plus 25 to 30 per cent. impact allowance and a partial crowd load at 56 pounds per square foot in some cases. These bridges are meeting the needs of heavy road transport of the present day. The bridges were either of masonry arches or of steel superstructure on masonry piers and abutments.

69. The loads specified by Mr. Blaber as Chief Engineer of Bihar and Orissa P. W. D. (in about 1921) for Reinforced cement concrete bridges were:—

Dead load:—Reinforced cement concrete slab at 150 pounds per cubic foot. Stone metal average thickness 6 inches at 140 pounds per cubic foot. (These correspond to B. S. Specification for weights of different materials).

Live load:—(*a*) Main girders 100 foot span—one ten-ton steam road roller *plus* 15 per cent. impact or a crowd of people at 65 pounds per square foot whichever is greater.

(*b*) Main girder, 60 foot span—one ten-ton road roller *plus* 25 per-cent. impact or a crowd of people at 75 pounds per square foot whichever is greater.

(*c*) Cross girder—A back axle load of 6 tons (3 tons on each wheel) *plus* impact allowance of 30 per cent. or a crowd of people at 85 pounds per square foot whichever is greater.

(*d*) Cross girder stringers—A front roller of 4 tons *plus* 30 per cent. for impact or a crowd of people at 85 pounds per square foot whichever is greater.

70. It might seem strange that the existing Howrah bridge was designed for a superload of only 28 pounds per square foot (full particulars may be found in a paper read by Sir Bradford Leslie in 1918). It has

so long discharged the most exacting duties put upon it quite creditably and can at this old age take 5 tons axle load on its shoulder quite safely. In the design of the new floating twin bridge, Sir Bradford Leslie took 84 pounds per square foot as the superload. In Mr. Mott's single span arch bridge design as well as in the German design (1920) 112 pounds per square foot was taken as the superload.

71. The Committee of Engineers appointed by the Government of Bengal in 1921 to advise Government as to the most suitable type of bridge to be constructed on the Hooghly to connect Calcutta with Howrah, recommended that the following loadings should be provided for on the carriage way of the single span cantilever bridge:—

(*a*) Tram cars having a bogie wheel-base of 18 feet and a total load of 25 tons.

(*b*) Motor lorries with 4 tons on front and 12 tons on back axle spaced 12 feet apart.

(*c*) Steam rollers, weighing 15 tons with 6 tons on front and 9 tons on back axle, spaced 11 feet apart.

(*d*) Tractors with 10 tons on front axle and 12 tons on back axle, spaced 10 feet apart, followed by boiler trucks with 25 tons on each axle spaced 12 feet apart, the distance between the back axle of the tractor and the front axle of the boiler truck being 10 feet.

For the purpose of the design of all subsidiary members directly affected, such as floor beams and secondary trusses, the above mentioned moving loads would be taken as concentrated loads.

Impact addition of 40 per cent. for tram cars and 50 per cent. for motor lorries and no impact addition for steam rollers or tractors were also recommended.

72. They also recommended that in computing the load for the main members an allowance should be made for a continuous stream of tram cars on both tracks.

They recommended a 76 feet carriage way on the bridge (18 feet for two lines of tramway and 58 feet for 6 lines of traffic) and 24 feet for the two footpaths to be placed outside the main girders or a total width of 100 feet.

73. Several reinforced cement concrete bridges have either been constructed or designed within the last few years and the following loads were adopted, as far as could be ascertained.

(1) *Wardha river bridge, Central Provinces.*—(105 feet span—reinforced concrete vault arches of filled spandril type with 19 feet clear roadway between kerbs)—12 B. E. S. A. units with appropriate allowance for impact or an equivalent uniform load of 150 pounds per square foot of roadway.

(2) *Bansodora Bridge.*—(Ribbed arch bridge 16 × 105 feet span.—One ten ton roller (12½ tons in working order) followed by a 5 ton motor lorry (11 tons gross weight) and 80 pounds per square foot as crowd load on the rest of the area. The back axle load of the roller was taken as 7 tons and that of the lorry the same.

(3) *Seethanagram Bridge, Vizagapatam.*—60 feet span bowstring girder bridge—same load as in (2).

(4) *Buckland Road Overbridge*, Howrah.—12 B. E. S. A. units of loadings with 50 per cent. impact addition (span 30 feet).

(5) *Nerbudda Bridge*, Jubbulpore.—Reinforced concrete vault arches of the filled spandril type; 98 feet clear span and 19 feet clear roadway.

Live load.—One 15 ton road roller with 50 per cent. impact and human load of 84 pounds per square foot over the rest of the area.

74. The following steel bridges were designed for the following super loads:—

(1) *Sambalpore State*—

(*a*) 3 × 100 feet span steel truss bridge with 14 feet roadway. One 10-ton roller or 80 pounds crowd whichever is greater.

(*b*) 7 × 25 feet span—14 feet roadway. One 10-ton roller or a crowd of people 84 pounds per square foot.

(2) *Assam, P. W. D.*—

5 × 100 feet span × 15 feet roadway.

Live load—One ten-ton road roller or 90 pounds per square foot as a crowd load.

75. The loadings adopted (by Messrs. Bird & Co.) in almost all the reinforced concrete bridges appear to me to be too high. Owing to massiveness and rigidity of concrete structures, the greater portion of the shock of the moving vehicles will be absorbed by them and so the effective impact addition on the static load of the vehicles will be much less than what it would be in steel bridges. Moreover with the introduction of pneumatic or rubber tyres on all classes of mechanically propelled vehicles for protection of roads, the dynamic effect of load on the bridge will be further reduced. Makers of motor vehicles also are endeavouring to reduce the unsprung weight of the vehicles to as low a figure as possible. It should also be borne in mind as mentioned before that the strength of concrete structures increases with age.

76. Road bridges in India are generally of spans ranging from 10 to 25 feet, 30, 60, 100 and 150 feet. Spans greater than 150 feet are rarely to be constructed. Spans between 10 to 20 feet are usually built in the simple slab form either monolithic with supports or the slabs are cast on masonry abutments. Bridges of 30 feet span are very common for which beam type is suitable. The beams may be continuous over several supports for a bridge consisting of a series of openings or may be of separate beams for each span simply supported on ends. Reinforced concrete beam bridges up to 60 feet span can be built now a days easily.

For a 50 to 100 feet span, an arch type of bridge is found suitable and for spans of 80 to 200 feet or above either arch or bow string girders bridges are generally built.

77. From these discussions, it will appear that if our bridges on main and arterial roads are designed for a 12-ton tractor or four wheeled Sentinel S/4 type of motor vehicle followed by a trailer of 8 tons gross weight with appropriate addition for impact, they will be sufficiently strong to carry the heavy traffic of mechanically propelled vehicles not only for the present but for very many years to come, *i.e.*, for the life time of the bridge. The bridge designed for this loading will safely take a 12-ton steam road roller with 25 per cent. impact or a 15-ton tractor. I, therefore, think that for bridges on all motorable roads, whether they be main or arterial

for trunk roads and on country roads in general, loadings as shown in figure 8 can be safely adopted with 25 per cent. addition for impact and this load should be for a 10 feet lane of traffic. For spans of 80 feet or over uniform loads as recommended in the Military Engineer Services Handbook, Vol. III (1930 edition) may be adopted *plus* an invariable knife edge load of 11,200 pounds per 10 feet lane to be so placed as to give maximum stress in any member. Up to 80 feet span the equivalent load is to be calculated as

$$\frac{\text{Moment for the train loads}}{(\text{Span})^2 \times 10} \times 8 \text{ lbs per s. ft.}$$

78. The Committee of the American Concrete Institute on reinforced concrete highway bridges recommended the following loads.

Span:—	Under 80 feet.	80 to 100 feet.	100 to 125 feet.	125 to 150 feet.	150 to 200 feet.	Over 200 feet.
Uniformly distributed loads in lbs per s. ft.	100	90	80	75	65	60

79. The French Government specified the following uniformly distributed loads for the design of bridges on the premier roads in France (*i.e.*, on national highways).

The regulation standard lorry loads, as shown before, are to be applied to members less than 65 feet in length and for a traffic lane of 8·2 feet (2·5 metres), the wheel track being taken as 5 feet 6 inches. For greater spans only the uniformly distributed superload (over the entire area of carriage way) is to be taken in the calculation with addition for impact in both cases. The value of the uniformly distributed load is to be found from the formula:—

$$P = 168 - \frac{L}{4}$$

where P = superload in pounds per square foot.

L = length of span in feet.

The value of P is limited to a minimum of 102 pounds (500 Kg. per square metre).

Impact addition is to be made to the values thus obtained. The impact addition is to be calculated from the following formula.

$$1 + \frac{0 \cdot 4}{1 + 0 \cdot 06 \text{ span of a member in feet}} + \frac{0 \cdot 6}{1 + 4\,\frac{\text{total dead load}}{\text{total live load.}}}$$

For footways, a superload of 82 pounds per square foot (400 Kg. per square metre) is recommended. In *Germany*, 500 Kg. per square metre, which is equal to 102 pounds per square foot, is recommended for road bridges of spans less than 50 feet. The German impact formula is 1·4 − 0·0015 L, *i.e.*, the maximum is 40 per cent.

80. As all works in India are being done according to B. E. S. A. specifications, it would be convenient to use the same standard in this case also instead of adopting a new standard of our own. The B. S. I.

loading is intended to be adopted all over the world and therefore that loading is shown on a unit basis. I, therefore, think that we should adopt:—

(1) *For bridges in non-industrial centres.*—Ten units of B. E. S. A. loading (8 units *plus* 25 per cent. impact) for the design of bridges on all roads which at present carry or may carry in the future motor transport, up to 80 feet span and for spans of 80 to 300 feet a straight line reduction from 10 to 6 units without any addition for impact. The unit load of the back axle of the tractor is to be taken as equal to 1 ton.

(2) *For bridges in industrial centres.*—Ten B. E. S. A. units for spans up to 100 feet and for spans from 100 feet to 300 feet a straight line reduction to 8 units, *plus* appropriate addition for impact may be adopted, to meet all possible contingencies, that may arise during the life time of a bridge, although I am of opinion that 12 B. E. S. A. units without impact addition will be enough to meet the normal demands in industrial areas as well and in view of the fact that for exceptional cases it is permissible to increase the stresses by 25 to 30 per cent. But where such bridges are intended to carry tramways, etc., special loadings are to be adopted. Impact addition has been taken at 25 per cent. in view of the facts that concrete bridges have more shock absorbing capacities than steel bridges and that heavy lorries are being prohibited to use solid tyres for the protection of roads and also due to the reduction of unsprung weight of vehicles by scientific springing of the body and also due to the restriction of speed of heavy vehicle (locomotive or motor tractor drawing trailers) from 5 to 8 miles per hour. Iron-tyred vehicles are rare in this country and the new rules will not permit any mechanically propelled vehicle to be fitted with any other than pneumatic tyres. The rules framed under the Great Britain Road Traffic Act of 1930 enforced the use of pneumatic tyres in locomotives. tractors and trailers and all vehicles from 1st January 1933. The old vehicles have been allowed time to run till 1940 by which time they will also be superannuated. The same principle must apply more forcibly for Indian roads.

81. The road roller impact stress will also never exceed 25 per cent of the static load in view of its very slow motion. For spandril filled arched bridges, the earth cushion will absorb a greater percentage of shock and only a small portion of it will be carried to the structure, if the cushion over the crown of the arch is not of sufficient depth. The mass of concrete in this type of bridge is so much that the dynamic effect of loads will be very much less than in other types of structure. It may also be noted that the new Buckland Road overbridge at Howrah—one of the highly developed industrial towns of India—had been designed for 12 B. E. S. A. units with 50 per cent. addition for impact (*vide* design made by Messrs. Bird & Co., of Calcutta). Impact allowance of 50 per cent. appears to me to be too high.

82. For unimportant village roads which will never be motorable, as for example bridle roads or pack transport roads, the loadings as recommended in the Military Engineer Services Handbook may be adopted as an all-India standard.

[Equivalent uniformly distributed loadings adopted in different countries ...wn in fig. 10 and Appendix V.]

PART V.

Impact on Road Bridges.

83. A moving load sets up greater stress than a static load and impact is the measure of this increment and is expressed as a fraction of the static live load stress. The problem of finding out the dynamic effect of rolling loads on highway bridges is a thorny one. Several formulæ have been advocated but all of them are more or less empirical and the results obtained from them widely differ and no rational expression for impact has yet been found. Experiments have been carried out in America to ascertain the effect of the impact of motor vehicles running on different classes of tyres on road surface.

84. A 2-ton motor vehicle was run over a device which was let into the road surface at the rate of 16 miles per hour. The results obtained are as follows:—

The static load of the rear wheel was taken in the calculation:—

(1) The effect of impact with pneumatic tyres	$=1\frac{1}{2}\times$	static load
(2) The effect of impact with cushion or hollow tyres	$=3$	do.
(3) The effect of impact with solid tyres	$=4$ to $5\times$	do.
(4) The effect of impact with steel tyres	$=7\times$	do.

85. There are though various formulæ for finding out the impact factor but none of them gives a correct figure and they are by no means final. It is extremely difficult to determine this factor on a highway bridge, as it depends on a number of variables which are mainly:—

(1) The span of the bridge.

(2) The ratio of live to dead load.

(3) The size of the driving wheels.

(4) The speed of vehicles.

(5) Nature of tyres

(6) Whether the vehicle is sprung or unsprung.

(7) Type of bridge, *i.e.*, nature of the structure.

(8) Material of which the bridge is composed.

(9) The condition of road surface and the material of which the surface is composed.

(10) Character of traffic.

86. The span remaining same, the other factors being variable, the value of impact cannot be the same in all cases for the same loaded length. It is therefore essential in order to reduce the impact stress to some extent that the road surface of the bridge must always be kept free from bumps, ruts or potholes.

87. The following are the recognised formulæ for finding out the impact factor.

(1) *British Standard (1925 Provisional formulæ)*—

Impact factor $I = \dfrac{80}{90 + \left\{\dfrac{n+1}{2}\right\} L}$ Where L=loaded length in feet,

$n = \dfrac{\text{Width of carriage way in feet.}}{10}$

I=Impact factor (to be multiplied to the live load to get the increment to be added to the Static live load).

The maximum value of "I" is not to exceed 70 per cent. for road bridges. The Ministry of Transport has adopted 50 per cent. addition to the concentrated load for impact on all classes of road bridges and for all spans. But it allows the impact factor to be reduced to 25 per cent. for concrete or masonry arches, provided temperature, arch shortening and shrinkage effects are allowed for in the calculations and the cover over the crown is reasonable.

(2) *Dr. Waddell's Formula (1921)*—

$I = \dfrac{100\,x}{nL + 200}$ (adopted by U. P., P.W.D.).

Where L=length of span in feet covered by the load.

$n = \dfrac{\text{Total road width (including footpath).}}{20}$

x=1·25 for Stiffened Suspension bridges.

=1·00 for steel bridges with open or light floors.

=0·75 ,, ,, with heavy solid floor of reinforced concrete.

=0·50 for reinforced concrete structures except spandril filled arch bridges.

=0·25 for spandril filled arch bridges.

(3) *Dr. Faber's Formula*—

$I = \dfrac{100}{100 + \dfrac{60\,L}{S}}$ Where S=speed of traffic in miles per hour.

This formula is obviously intended for railway bridges.

(4) *American Railway Eng. Association's Formula*—

$I = \dfrac{300}{nL + 300}$ Where $n = \dfrac{\text{width of road in feet.}}{20}$

L=loaded length in feet.

(*a*) For railway traffic—100 per cent. of the value of "I" as obtained from the above formula is to be taken.

(*b*) for Electric tram car traffic—50 per cent. of the value is to be taken.

(*c*) For motor lorry traffic—30 per cent.

(*d*) For steam road rollers and other slow moving traffic—25 per cent. of the value to be taken.

This formula has been adopted in the "Military Engineer Services Hand Book".

(5) *American Society of Civil Engineer's recommendations*—

(*a*) For Floor beams and Stringers.—Impact addition 30 per cent. of live load.

(*b*) For Floor beam hangers—Impact addition 60 per cent. of live load.

(*c*) For girders and trusses $I = \frac{100}{L + 300}$

In all the above formulæ L = "loaded length" of span in feet, *i.e.*, the length of span loaded to produce the maximum stress in the member considered.

(6) *Mr. Ketchum's recommendations*—

(*a*) For spandril filled concrete arches and culverts with minimum filling of 1 foot—No impact addition.

(*b*) For concrete slab and girder bridges and trestles and arches without spandril filling—Impact addition 30 per cent of live load.

(*c*) For steel bridges, on the floor system members—Impact addition 30 per cent. of live load.

(*d*) For all truss members other than the floor, and its supports ... ... $I = \frac{100}{L + 300}$

Where L = length of span for simple highway bridges.

For trestle bends, towers, moveable arch and cantilever bridges and for bridges carrying electrical trains, "L" shall be taken as the "loaded length" of the span in feet producing maximum stress in the member.

(7) *French P. W. D. Formula*—

$$I = 5\left(\frac{0 \cdot 4}{1 + 0 \cdot 06\,L} + \frac{6}{1 + \frac{4P}{S}}\right)$$

Where L = span of member in feet.

P = total dead load carried by the member including its own weight.

S = total live load carried by the member.

(8) *German Formula for Impact*—

$I=(0{\cdot}4-0{\cdot}0015\ L)$

(9) *Am. Asso. of State Highway Officials' formula (1931)*—

$I=\frac{50}{L+125}$ Where L=loaded length

Their 1923 formula was $I=\frac{L+250}{10L+500}$

(10) *Canada Standard*—

Impact addition is 30 per cent of live load.

(11) *Punjab P. W. D. adopted the formula*—

$I=\frac{1}{2}\times\frac{65}{45+L}$, subject to a maximum of 50 per cent.

(12) *Iowa State Highway Commission's specification (1923) for impact for Highway bridges (steel bridges)*—

(*a*) For I—beams and floor system of trusses and girders the impact is to be taken on $33\frac{1}{3}$ per cent of live load.

(*b*) For floor beam hangers—$66\frac{2}{3}$ per cent.

(*c*) For trusses and through girders $I=\frac{75}{L+200}$.

Where L=loaded length of span in feet.

(13) *West Virginia and Oregon Highway Commission*—

$I=\frac{100}{L+300}$ Where L=loaded length in feet.

(14) *Montana Highway Commission*—

I=25 per cent. of the live load.

(15) *U. S. Bureau of Public Roads*—

I=30 per cent. of the live load.

88. The table in appendix VI will show at a glance that the results obtained from different formulæ widely differ and we are simply in the dark about the impact stress that is actually induced in a road-bridge due to moving loads. Fig. 11 may also be seen. The maximum impact co-efficient according to Dr. Waddell's formula works out to 25 per cent. in case of concrete bridges and so my suggestion about the adoption at a flat rate of 25 per cent. impact co-efficient cannot be considered as too low. The impact co-efficient according to the new German formula works to a maximum of 40 per cent. only.

Impact Coefficient Curve according to various formulae

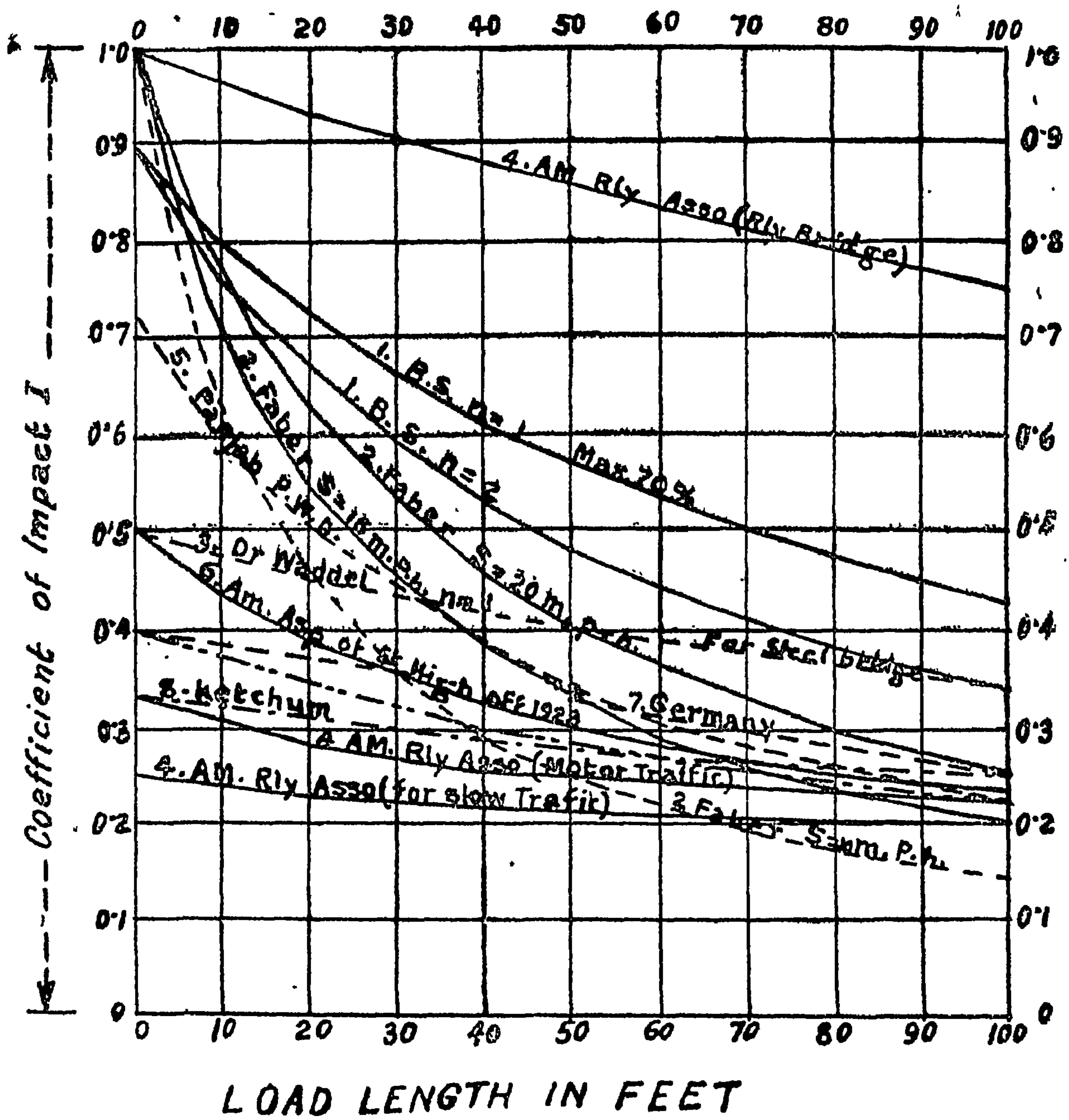


Fig 11

APPENDIX II.

Approximate running cost of Leyland Lorries of various capacities.

Both Petrol and Oil driven.

asis of Calculations :—

(*a*) Annual Milage 25,000.
(*b*) Economical Life of vehicle for purposes of depreciation—150,000.
(*c*) Depreciation at the rate of 1/6th value of machine less tyres per annum.
(*d*) Cost per mile for tyres one anna average for all models.
(*e*) Cost of petrol Rs. 1-8-0, this being an average price in India.
(*f*) Cost of fuel oil Rs. 0-9-0, this being an average price in India.
(*g*) Petrol consumption 4/5 Tonner 10 MPG, 6 Tonner 8·5, 8 Tonner 7·5, 12 Tonner 6, 15 Tonner 5.
(*h*) Fuel oil consumption 4/5 Tonner 18 MPG, 6 Tonner 16, 8 Tonner 14, 12 Tonner 10, 15 Tonner 8.
(*i*) Lubricating oil consumption 750 MPG at Rs. 4 per gallon average throughout life for all models.
(*j*) Maintenance per mile 5 Tonner 9 pics, 6 Tonner, 10 pies, 8 Tonner 11 pies, 12 and 15 Tonner 1 anna, this includes chassis lubrication.

Models.	4/5 Tonner CUB.	6 Tonner BEAVER-4.	8 Tonner BEAVER-6.	12 Tonner HIPPO.	15 Tonner OCTOPUS.
	Rs.	Rs.	Rs.	Rs.	Rs.
Approximate cost of Petrol Chassis and Platform Body, less tyres.	6,000	10,470	12,100	18,570	21,250

STANDING CHARGES PER ANNUM.

Depreciation	1,000	1,745	2,015	3,095	3,540
Interest at 5 per cent. on declining balance.	175	305	352	540	620
Driver's and Mate's Wages.	720	720	840	960	960
Garage	250	250	250	250	250
License (Say)	400	500	600	700	800
Insurance (Say)	300	400	400	500	500
Establishment	500	500	500	500	500
Total Standing Charges	3,345	4,420	4,957	6,545	7,170

RUNNING EXPENSES PER ANNUM.

Petrol	3,750	4,410	5,000	6,250	7,500
Engine Oil	132	132	132	132	132
Tyres	1,565	1,565	1,565	1,565	1,565
Maintenance	1,170	1,300	1,432	1,565	1,565
Total Running Expenses	6,617	7,407	8,129	9,512	9,762
Total Operating Costs per annum.	9,962	11,827	13,086	16,057	16,932
Cost per ton mile	1 anna 5·0 pies.	1 anna 3·1 pies.	1 anna 0·1 pie.	10·3 pies.	8·7 pies.

Models.	4/5 Tonner CUB.	6 Tonner BEAVER-4.	8 Tonner BEAVER-6.	12 Tonner HIPPO.	15 Tonner OCTOPUS.
Approximate cost of Diesel Engined Chassis with platform body (less tyres).	Rs. 8,430	Rs. 12,550	Rs. 14,530	Rs. 21,000	Rs. 23,680
STANDING CHARGES PER ANNUM.					
Depreciation . .	1,405	2,000	2,420	3,500	3,950
Interest at 5 per cent. on declining Balance.	245	366	425	610	690
Driver's and Mate's Wages.	720	720	840	960	960
Garage . . .	250	250	250	250	250
License . . .	400	500	600	700	800
Insurance . . .	300	400	400	500	500
Establishment . .	500	500	500	500	500
Total Standing Charges .	3,820	4,826	5,435	7,020	7,650
RUNNING EXPENSES PER ANNUM.					
Fuel Oil . . .	782	877	1,005	1,406	1,760
Engine Oil . . .	132	132	132	132	132
Tyres	1,565	1,565	1,565	1,565	1,565
Maintenance. . .	1,170	1,300	1,432	1,565	1,565
Total Running Expenses	3,649	3,874	4,134	4,668	5,022
Total Operating costs per annum.	7,469	8,700	9,569	11,688	12,672
Cost per ton mile . .	*12·8 pies.	11·7 pies.	9·2 pies.	7·5 pies.	6·5 pies.

* On the basis of a 4½ ton load.

APPENDIX

PARTICULARS OF HEAVY

Serial No.	Maker's Name.	Pay Load in tons.	Weight of chassis and body.	Weight laden in gross weight.	Weight on front axle.	Weight on 2nd axle for 6 wheelers.	Weight on 3rd axle for 8 wheelers.	Rear axle weight.	Wheel base for 4 wheelers.
			T. C. Q.	T. C. Q.	T. C. Q.	T. C. Q.	T. C. Q.	T. C. Q.	Ft. In.
1	Associated Equipment Co.	5 to 6	3 10 0	10 0 0	3 6 3	...	...	5 2 1	12 6
2	Ditto .	.10 to 12	5 0 0	15 0 0	5 0 0	5 12 0	...	4 0 0	12 6
3	Albion . .	6	6 1 2	8 4 1	2 14 3	...	...	5 9 2	17 9
4	Scammel . .	8 to 9	7 12 0	15 18 0	2 1 0	6 12 0	...	7 5 0	21 10
5	Thornycroft Ltd. .	10	7 3 0	17 3 0	...	...	...	...	...
6	Do. Speedy .	7 to 8	2—10 Tractor 2—4 Trailer	11 10 0	...	...	...	...	...
	Ditto .	3½	3 13 1	7 3 1	2 15 1	...	...	4 8 0	13 0
8	Ditto .	5	4 13 3	9 13 3	4 13 1	...	...	5 0 0	14 6
9	Ditto .	7	5 4 0	12 4 0	5 10 0	...	...	6 14 0	16 0
10	Leyland— S. Q. 2 . .	6 to 7	5 18 0	11 13 0	3 8 3	...	...	8 4 2	14 4
11	(Buffalo) T. Q. I .	6	5 15 0	11 2 0	3 5 2	...	...	7 16 2	16 9
12	Terrier T. E. I. .	3 to 4	4 18 0	8 9 0	2 2 2	3 3 2	...	3 3 2	...
13	Special T. E. 5 .	6	8 0 0	11 13 0	2 17 2	4 7 0	...	4 7 0	...
14	T. S. W. 7 D. .	12½	7 5 0	19 0 0	5 3 1	6 18 1½	...	6 18 1½	...
15	T. E. W. 8 D. (Octopus).	14 to 15	6 14 3	22 0 0	3 0 0	3 0 0	7 10 0	7 10 0	...
16	Walford Trailers .	5	1 10 0	6 10 0	3 5 0	...	...	3 5 0	9 7
17	Fowler Trailers .	...	...	8 10 0	4 0 0	...	...	4 10 0	7 0
18	Fodden Steam Wagon.	5	7 10 0	12 10 0	4 5 0	...	...	8 5 0	14 0
19	Leyland (Hippo) .	12 9 0	6 11 0	19 0 0	4 0 0	7 10 0	...	7 10 0	16 10½
20	Sentinel— S/4 (Steamer) .	6 5 2	5 5 0	11 7 2	4 6 0	...	...	7 14 0	11 6 / 12 11
21	S/6 (Steamer) .	10 6 2	6 12 0	17 8 2	...	...	...	...	...
22	S/8 (Steamer) .	12 13 2	7 15 0	22 10 0	3 5 0	3 5 0	8 0 0	8 0 0	...
23	Trailers . .	4-5 Flat	1 8 0	6 8 0	...	...	...	...	...
24	Trailers . .	6-7 Flat	1 15 0	8 15 0	...	...	...	...	...
25	Trailers . .	10 Flat	2 10 0	12 10 0	...	...	...	...	...
26	Trailers . .	6-7 Tipping	2 15 0	9 15 0	...	...	...	...	...
27	Thornycroft Lorry	6	...	10 11 1	4 0 3	...	...	6 10 2	15 6
28	Leyland lorry .	12	...	18 19 2	3 19 3	7 9 3	...	7 9 3	...
29	Scammel lorry .	15	...	22 0 0	4 0 0	8 0 0	...	10 0 0 in 4 wheels	...
30	Garret (Steam) lorry	6	...	12 0 0	4 0 0	...	...	8 0 0	11 4
31	Sentinel (Steam) lorry.	12 to 15	...	19 0 0	4 19 0	7 0 2	...	...	...

III.

Motor Vehicles.

Distance between 1st & 2nd axle.	Distance between 2nd & 3rd axle.	Distance between 3rd & 4th axle.	Wheel track front.	Wheel track rear.	Tyre front.	Tyre rear.	Overall length.	Overall breadth.	Remarks.
Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Single.	Twin.	Ft. In.	Ft. In.	
...	...	...	6 1¾	6 1¾	920×120	920×120	20 3	7 2¼	
...	...	...	6 1¾	6 1¾	920×120	920×120	...	...	6 wheelers.
...	...	...	5 10⅜	5 10⅜	22—230	22—230	27 6	7 6	4 wheeler Omnibus. One in Bombay.
...	...	...	6 6	7 6	40×8″	40×8″	28 0	7 6	6 wheeler. One in Bombay.
10 0	13 6	...	6 4	6 1	40×8″	40×8″	32 0	7 6	6 wheeler Trailer.
11 0	11 6	...	5 0¼	5 4¾	34×7″	34×7″	28 6⅛	...	Articulated 6 wheeler.
...	...	...	6 3½	5 11	36×5″	36×5″	...	...	4 wheeler.
...	...	...	6 1½	5 11	40×6″	40×6″	...	...	Do.
...	...	...	6 4¾	6 1¼	40×6″	40×6″	...	...	Do.
...	...	...	5 8	5 11	8″ solid	8″	22 8	6 11	Do. One in Calcutta.
...	...	...	6 2	5 8	8″	8″	25 2	7 6	Do. One in Bombay.
11 2	3 8	...	5 8	5 9	9″	9″ S (C & R)	20 5	7 0	6 wheelers. Six in India
14 0	3 8	...	6 3	6 3	9″	12″ S (C & R)	23 9	7 6	6 wheeler. 5 in Burma. 1 In Assam.
16 8	4 5	...	6 4	5 10	9″	...	...	...	6 wheeler. None in India.
4 6½	12 4½	4 5	6 4½	5 0½	40×9″	13-5 (S)	26 10½	7 5	Do. 8 wheeler.
...	...	...	5 10	5 10	670×120	670×120	...	...	
...	...	...	4 6	4 6	8″	8″	...	...	
...	...	...	...	...	850×160	850×160	...	...	
14 7¾	4 5	...	6 4½	5 9½	40×9″	38×8″	20 10¾	7 5	6 wheeler Rigid.
...	...	...	6 4½	5 8	38×8″	38×8″	21 0	7 5¾	Steam Wagon.
12 6⅛	4 0	...	6 4½	5 8	38×8″	38×8″	22 8⅞ 25 5⅞	7 5¾	6 wheeler Rigid.
3 5½	10 8	4 0	6 4¾	5 8	36×7″	38×8″	27 7¾	7 5⅝	8 wheeler Rigid
...	...	...	...	...	34×7″	34×7″	12 6to 13 6	...	
...	...	...	...	...	38×8″	38×8″	13 6to 17 0	...	
...	...	...	...	...	34×7″T	34×7″T	15 3to 20 0	...	Twin tyres on all wheels.
...	...	...	...	...	38×8″	38×8″	12 6	...	
...	...	...	...	5 10	...	...	24 11	7 6	
14′ 11	4 2	...	...	5 10	...	...	27 4	7 6	6 wheelers.
10 0	15 0	...	...	2′-2′-1″-2′-0	...	...	33 0	7 6	8 wheelers with 3 axles.
...	...	...	...	5′ 8″	...	...	20 10	7 3	Steam Tipping Wagon.
12 7	3 10	...	...	5′ 9″	...	...	20 3	7 5	6 wheeler.

APPENDIX

Particulars of Steam

Serial No.	Maker's Name.	Nominal weight of rollers in tons.	Weight Empty.	Weight in running order.	Overall length of the Engine.	Wheel base.	Track of rollers.	Diameter of hind rollers.
			T. Cwt.	T. Cwt.	Ft. In.	Ft. In.	Ft. In.	Ft. In.
1	Wall's and Steevens, Ltd.	3	2 19	3 9	11 3	7 1	3 6	3 9
		6	5 19	6 14	14 4	8 7	4 1	4 0
		8	7 18	8 13	14 4	8 7	4 1	4 0
		10	10 1	10 19	15 6	9 9	4 6	4 6
2	John Fowler & Co., Ltd. .	6	8 0	8 15	16 4	9 9	4 4	5 0
		6	8 5	9 0	16 4	9 9	4 4	5 0
		8	10 0	11 0	17 9	10 8	4 8	5 3
		8	10 10	11 10	17 9	10 8	4 8	5 3
		10	11 10	12 10	18 4	10 8	5 0	5 3
		10	12 0	*13 0*	18 4	10 8	5 0	5 3
		12	12 15	13 15	18 7	*10 8*	5 1	5 6
		12	13 5	*14 5*	18 7	*10 8*	5 1	5 6
		14	13 15	14 15	19 5	11 7	5 4	5 7
		14	14 5	15 5	19 5	11 7	5 4	5 7
3	Aviling and Porter . .	6	6 0	7 7	16 1	9 8	4 5	4 9
		8	8 0	8 9	16 1	9 8	4 6	4 9
		8	8 0	10 6	17 11	10 11	4 9	5 0
	Burford and Perkins	...	9 1	10 15	17 5	8 9	4 11	5 0
		...	11 12	13 16	18 1	9 10	4 11	5 0
		...	12 13	14 17	18 1	9 10	5 1	5 0
	Do. Tandem Type .	...	5 13	6 2	13 8	9 2	...	3 0
		...	8 1	9 13	14 0	9 11	...	3 6
	Marshall Sons & Co. .	6	7 14	8 10	16 1	9 6	5 0	4 9
		6	8 1	8 17	16 1	9 6	5 0	4 9
		8	10 0	10 16	16 2	9 6	5 0	5 0
		8	10 3	10 19	16 2	9 6	5 0	5 0
		10	12 13	*13 15*	18 11	*11 4*	5 1	5 6
		10	13 0	*14 3*	18 11	*11 4*	5 1	5 6
		12	13 14	14 17	18 11	11 4	5 2	5 6
		12	14 0	*15 3*	18 11	11 4	5 2	5 6
		14	14 12	15 19	28 1	13 2	5 9	6 0
		14	14 17	16 4	28 1	13 2	5 9	6 0

IV.

AND OIL ROAD ROLLERS.

Width of hind rollers.	Diameter of front rollers.	Width of front rollers.	Total width rolled.	Weight on front rollers in working order.	Weight on both hind rollers in working order.	B. H. P. of Engine.	Working Pressure.	
Ft. In.	Ft. In.	Ft. In.	Ft. In.	T. Cwt.	T. Cwt.		lbs.	
1 6	3 0	2 6	5 0	1 13	1 16	8·5	130	
1 11	3 6	2 9	6 0	2 16	3 18	24	140	
1 11	3 6	2 9	6 0	3 17	4 10	26	150	
2 0	3 9	3 0	6 6	4 0	6 19	30	140	
1 4	3 6	3 6	5 8	2 18	5 17	20	140	Single.
1 4	3 6	3 6	5 8	3 0	6 0	20	200	Compound.
1 8	3 8	3 11	5 11	3 13	7 7	23	140	Single.
1 8	3 8	3 11	5 11	3 16	7 14	23	200	Compound.
1 5	3 8	4 0	6 5	4 3	8 7	26	140	Single.
1 5	3 8	4 0	6 5	4 6	8 14	26	200	Compound.
1 6	4 0	4 1	6 7	4 11	9 4	26	140	Single.
1 6	4 0	4 1	6 7	4 15	9 10	26	200	Compound.
1 6	4 0	4 3	6 10	4 18	9 17	30	140	Single.
1 6	4 0	4 3	6 10	5 1	10 4	30	200	Compound.
1 3	3 3	3 6	5 8	2 6	5 1		140	
1 4	3 3	3 6	5 10	3 1	5 8			Colonial.
1 3	3 6	3 10	5 12	3 15	6 11		140	Ordinary.
1 5	3 6	4 2	6 4	3 6	7 9	32 35		
1 5	4 0	4 2	6 4	4 13	9 2	32 35		Run on crude oil.
1 7	4 0	4 2	6 9	5 0	9 17	32 35		
4 0	2 9	3 0	4 0	2 2	4 0	28		Petrol Driven.
4 0	3 0	4 0	4 0	3 13	6 0	28		Do.
1 3	3 3	4 0	6 3	2 16	5 14	16	180	Single.
1 3	3 3	4 0	6 3	2 19	5 18	16	200	Compound.
1 3	3 6	4 2	6 3	3 10	7 6	16	180	Single.
1 3	3 6	4 2	6 3	3 12	7 7	16	200	Compound.
1 4	4 0	4 3	6 5	4 11	9 4	20	150	Single.
1 4	4 0	4 3	6 5	4 14	9 9	20	180	Compound.
1 5	4 0	4 3	6 7	4 17	9 18	20	150	Single.
1 5	4 0	4 3	6 7	5 3	10 0	20	180	Compound.
1 6	4 3	4 0	7 3	4 18	11 1	30	150	Single.
1 6	4 3	4 9	7 3	4 19	11 5	30	180	Compound.

APPENDIX

TABLE OF EQUIVALENT UNIFORMLY DISTRIBUTED LOAD

(Based on centre moment for Ministry of Transport and B. S. Units) highway

Span in feet.	Load in pounds per sq. ft.						American Asso. of State Highway Officials 1923.			American Concrete Institute 1916.	
	12 B. S. Units.	12 B. S. Unit up to 100 ft. then reduced to 8 from 100-300 ft.	10 B. S. Units.	St. line reduction of 10 to 8 Units from 100 to 300 ft. span.	St. line reduction of 10 to 6 from 80 to 300 ft. span.	Military Engineers Services Handbook.	115-ton truck. For	120-ton truck. Steel gir	220-ton truck. ders.	Class A.	Class B.
5	1,075		896			896					
8	672		560			560					
10	538		448			450	For loaded length less than 50 ft.				
12	448		373			390	(a) 115-ton truck or 100 lbs./s. ft.				
15	358		298			300					
20	278		232			240	(b) 120-ton truck or 130 lbs./s. ft.				
25	250		208			210					
30	227		189			190	(c) 215-ton trucks and 220-ton trucks.				
35	208		173			170					
40	192		160			150					
45	185		154			140					
50	179		149			130	100	130	180		
60	166		138			120	96	122	168		
70	161		134			115	92	114	156		
80	*155*		*129*	*129*	*129*	*110*	88	106	144	*125*	*100*
90	150		125	125	123	105	84	98	132	110	90
100	*146*		*122*	*122*	*118*	*100*	*80*	*90*	*120*	*110*	*90*
120	143	138	119	117	110	95	76	86	114	100	80
140	139	130	116	111	103	90	72	82	108	90	75
150	138	127	115	109	100	92	70	80	105	90	75
160	138	124	115	108	98	85	68	78	102	85	65
180	138	120	115	106	94	80	64	74	96	85	65
200	138	115	115	104	90	75	60	70	90	85	65
250	137	103	114	97	79	70	60	70	90	80	60
300	137	91	114	91	68	70	60	70	90	80	60

NOTE.—For intermediate spans load,

V.

IN POUNDS PER SQ. FT. OF BRIDGE DECKING.

to show at a glance the loadings adopted in different countries for bridges.

American Asso. of State Highway Officials 1931.			Canada.			French P. W. D.	British Ministry of Transport 1922 based on centre moment.	Am. Asso. of State Highway Officials (1931) as in columns 13 to 15. Distributed uniform load in lbs./sq. ft. based on centre moment.		
Class AA H 20.	Class A H 15.	Class B H 10.	20-ton Truck U 100.	15-ton Truck U 80.	10-ton Truck U 7			Class AA H 20.	Class A H 15.	Class B H 10.
								25 per cent. impact is included in all cases.		
or loaded length of less than 60 ft. Truck loading to be taken.	Ditto.	Ditto.	100 lbs. s.ft. up to 100 ft. span.	80 lbs. s.ft. up to 100 ft. span.	70 lbs. s.ft. up to 100 ft. span.	$(108 - \frac{L}{4})$ lbs. s.ft. subject to a minimum of 102 lbs. s.ft. Lorry loading for members less than 65 ft. in length	1,970	1,776	1,334	889
							1,132	1,110	833	555
							980	889	667	444
							820	740	555	370
							656	592	441	296
							493	444	333	222
							430	356	267	178
							399			
							343	239	179	119
71	53	36					326	198	148	99
Plus	Knife edge	load of					309	168	126	84
2,000 lbs. and 2,890 lbs. per ft. width.	1,500 lbs. and 2,170 lbs. per ft. width.	1,000 lbs. and 1,450 lbs. per ft. width.				150	300			
						148	*293*	*137*	*103*	*69*
						145				
			100	*80*	*70*	*143*	*282*	*135*	*100*	*68*
For mom	ent and she	ar respec- tively.	96	76	66	138				
			92	72	62	133				
			90	70	60	131	269			
			88	68	58	128				
			84	64	54	123				
			80	60	50	118	272	131	98	65
			80	60	50	106				
			80	60	50	102				

are to be proportionately interpolated

APPENDIX

Comparative Results of Impact Co-efficients

For details please see the

Loaded length in feet.	1 British Standard maximum 70 %.		2 Dr. Fabers.			3 Dr. Waddel For n=1 (U. P. P. W. D.).		
	When n=1.	When n=2.	S=20	When S=15	S=10	For steel bridge 100%	For R/C. bridge 50%	For R/C. Spandril filled arch 25 %
0	0·89	0·89	1·00	1·00	1·00	0·5	0·25	0·125
10	0·80	0·76	0·76	0·71	0·62	0·48	0·24	0·12
20	0·73	0·67	0·62	0·55	0·45	0·45	0·22	0·11
30	0·66	0·59	0·53	0·45	0·35	0·43	0·22	0·11
40	0·61	0·53	0·45	0·38	0·29	0·42	0·21	0·10
50	0·57	0·48	0·40	0·33	0·25	0·40	0·20	0·10
60	0·55	0·44	0·36	0·29	0·22	0·38	0·19	0·09
70	0·50	0·41	0·32	0·26	0·19	0·37	0·19	0·09
80	0·47	0·38	0·29	0·23	0·17	0·36	0·18	0·09
90	0·44	0·36	0·27	0·21	0·16	0·34	0·17	0·08
100	0·42	0·33	0·25	0·20	0·14	0·33	0·16	0·08
110	0·40	0·31	0·23	0·18	0·13	0·32	0·16	0·08
120	0·38	0·30	0·22	0·17	0·12	0·31	0·15	0·08
130	0·36	0·28	0·21	0·16	0·11	0·30	0·15	0·08
140	0·35	0·27	0·19	0·15	0·11	0·29	0·15	0·07
150	0·33	0·25	0·18	0·14	0·10	0·28	0·14	0·07
160	0·32	0·24	0·17	0·13	0·09	0·28	0·14	0·07
170	0·31	0·23	0·16	0·13	0·09	0·27	0·14	0·07
180	0·30	0·22	0·15	0·12	0·08	0·26	0·13	0·07
190	0·28	0·21	0·14	0·12	0·08	0·25	0·12	0·06
200	0·27	0·20	0·14	0·11	0·08	0·25	0·12	0·06
250	0·24	0·17	0·11	0·09	0·07	0·22	0·11	0·06
300	0·21	0·16	0·10	0·08	0·07	0·20	0·10	0·05

VI.

DERIVED FROM DIFFERENT FORMULÆ.

formulæ in the note.

4			5	6		7	8	9	10	11
Am. Rly. Association (Adopted by Military Engineers India). N=1.			Punjab P. W. D.	Am. Association of State Highway Officials.		Germany.	Canada and U. S. Bureau of Public Roads.	Mont Highway Commission.	Virginia Oregon and Am. Soc. of Civil Engineers and Ketchum.	Ministry of Transport England.
For Rly. traffic 100%	For motor Traffic. 30%	For slow traffic 25%	Maximum 50%	1923 Formula	1931 Formula	0·4—·0015L				
1	0·33	0·25	0·72	0·50	0·40	0·40	Impact addition 30% of the live load.	Impact addition 25% of the live load.	0·33	Impact addition 50% of the live load.
0·97	0·29	0·24	0·59	0·43	0·37	0·39			0·32	
0·93	0·28	0·23	0·50	0·38	0·34	0·37			0·31	
0·91	0·27	0·23	0·43	0·35	0·32	0·36			0·30	
0·88	0·26	0·22	0·38	0·32	0·30	0·34			0·29	
0·86	0·25	0·21	0·34	0·30	0·28	0·33			0·28	
0·83	0·25	0·21	0·30	0·28	0·27	0·31			0·27	
0·81	0·24	0·20	0·28	0·27	0·25T	0·30			0·27	
0·79	0·24	0·20	0·26	0·25	0·24	0·28			0·26	
0·77	0·23	0·19	0·24	0·24	0·23	0·26			0·25	
0·75	0·23	0·19	0·22	0·23	0·22	0·25			0·25	
0·73	0·22	0·18	0·21	0·22	0·21	0·23			0·24	
0·71	0·21	0·18	0·19	0·22	0·20	0·22			0·24	
0·69	0·21	0·17	0·18	0·21	0·19	0·20			0·23	
0·68	0·20	0·17	0·17	0·20	0·19	0·19			0·23	
0·67	0·20	0·17	0·17	0·20	0·18	0·17			0·22	
0·65	0·19	0·16	0·16	0·19	0·18	0·16			0·22	
0·64	0·19	0·16	0·15	0·19	0·17	0·15			0·21	
0·62	0·19	0·16	0·14	0·19	0·16	0·13			0·21	
0·61	0·18	0·15	0·14	0·18	0·16	0·12			0·20	
0·61	0·18	0·15	0·13	0·18	0·15	0·10			0·20	
0·54	0·16	0·14	0·11	0·17	0·13	0·25			0·18	
0·50	0·15	0·13	0·09	0·16	0·12	0			0·17	

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Mr. M. G. Banerjee: Mr. Chairman and gentlemen:—My paper is about "The standardisation of loading for the design of highway bridges in India". I have said a lot in my paper and I had no intention of making further comments and waste your valuable time but as is customary I should say a few words just to invite your attention to some of the salient points in my paper.

At the outset, I must say that I owe you an apology for presenting before you such a bulky paper. The inflation is not effected simply by stuffing it in, with light and waste materials but with materials of very high intensities and values which make it weighty as well. The subject is a difficult and intricate one and cannot be lightly brushed aside. I have, therefore, endeavoured to deal with the question in all its bearings to the best of my knowledge and ability and I have placed before you all relevant facts and figures in order to bring home to you both the desirability and feasibility of having an all-India standard loading for highway bridges and to show that I have not jumped at a conclusion in putting forward my suggestions about the minimum standards to be adopted in the concluding paras. i.e., paras. 80 to 82 of part IV of my paper.

You are all aware that all the civilised countries of the world have standardised their specifications long ago and India is lagging behind in this respect also. Practically all the different States of America, which had their own specifications, a few years back, are now using the loading standards of the American Association of State Highway officials. If this is possible there why should it not be possible here in India. In 1929 I wrote a few articles in "Indian Engineering" about the design of highway bridges and culverts. (Now incorporated in my book entitled "Notes on the designs of bridges and culverts"). At that time I suggested that the question of standardisation of bridge loadings should be taken up by the road authorities of this country at the earliest moment, so that both inefficient and extravagent designs be avoided. Economy *cum efficiency* should be the watchword of every engineer entrusted with the expenditure of public funds.

In 1931, the Committee of Engineers made certain recommendations regarding this question (vide extracts given at pages 302—303). Their recommendations were also accepted by the Government Road Conference. But it appears that their recommendations have not been given effect to as yet as different provinces are still following their own specifications which are based on their provincial needs.

My paper is divided into 5 parts:—

(1) The first part deals with statistics showing phenomenal development of motor transport all over India since 1921 and the heavy traffic units which our roads are now subjected to carry and the need for an all-India standard specification for the design of highway bridges and I have given my reasons therefor.

(2) In the second part, I have shown the superloads specified in the various provinces of India and how they differ from one another. I could not include in my paper Indian Railway Board Bridge Rules and the draft Bengal P. W. D. rules. But these you can see in paper No. 27 which also advocates my views.

(3) In the third part I have shown the limitations imposed by the laws of the land on the running of heavy motor vehicles in the different provinces of this country. Extracts from the Great Britain Road Traffic Act of 1930 have also been given to show as to what extent the latitudes allowed in the old regulations have been curbed and crippled. The maximum permissible axle load and speed have now been considerably reduced and the use of pneumatic tyres on all classes of mechanically propelled vehicles has been made compulsory.

(4) In the fourth part, I have shown the minimum loadings prescribed for road bridges in some of the highly developed industrial countries of the world and the loadings proposed for Indian road bridges. Uniform equivalent loads for different spans have been worked out and are shown in Appendix V in a tabulated form to admit of easy comparison. From the comparative statement of loadings, you will find that my proposed standard is neither too high nor too low and if the bridges are designed for that standard, they will be able to meet the needs that may come upon them during their life time. The existing Howrah Bridge was designed for a superload of 28 pounds per square foot and it has so long discharged the most exacting duties put upon it quite creditably and is at this old age carrying a 5 ton axle weight on its shoulders with impunity.

(5) Part V deals with impact coefficients. Comparative results of impact coefficients for different loaded lengths worked out from the different recognised formulæ have been given in Appendix VI.

In dealing with the question of loading standards, I have raised a few other points, which directly affect the design of bridges. These are mainly:

(1) Width of roadway to be provided for each traffic lane and whether it is not desirable to have all of our new bridges provided with two traffic lanes. I think all the bridges which are to be constructed henceforth should have two traffic lanes of 18 feet width.

(2) Standardisation of motor vehicles rules (para. 62); Rules should be alike all over India.

(3) Increased working compressive stresses in cement concrete:

The permissible working stress of 600 pounds per square inch is still in operation. This is too low and should have been discarded long ago. It was adopted over a quarter of a century back, when the crushing strength of 1:2:4 cement concrete at 28 days was about 1,800 pounds per square inch or 2,400 pounds for square inch in 3 months. Now the crushing strength of 1:2:4 mix (i.e., ordinary concrete with 90 lbs of cement in the mix) varies between 5,000 to 6,000 pounds per square inch at 28 days (this is only 60 per cent. of the final crushing strength which will be obtained after one year) and allowing a factor of safety as high as 6 (six) we could still fix the permissible stress at 900 or 1,000 pounds per square inch. Concrete made even with brick aggregates has a crushing strength as high as over 4,000 pounds per square inch. All other conditions and factors remaining same, the strength of a cement concrete depends on the nature and quantity of aggregates. Concrete made with hard, tough fine grained basaltic trap will certainly have a higher crushing strength than concrete made with soft-quality of stone or with gravel or vitrified brick aggregate. Some tests were carried out at my request about the crushing strength of cement concrete of various mixes and with different

kinds of aggregates at the cement factory at Bundi and the results obtained are really astounding. Some test results are also given at page 308 of my paper. The Ministry of Transport, England, has now increased the working stress in concrete of 1:2:4 mix (i.e., with 90 lbs of cement) from 600 to 750 pounds per square inch but I think, as shown before, that it admits of further increase in this country.

(4) Increase of working tensile stress in steel.

The permissible tensile stress in steel should also be increased from 16,000 to 20,000 pounds per square inch, as lot of improvement has been effected in the manufacture of steel as well.

It is now up to you to decide whether the working stresses in both concrete and steel should not be increased with a view to economise design of reinforced concrete structures and if so to what extent. I have made certain observations about these points in paras. 58 and 59 of my paper. Mr. Turnbull has dealt with this question in detail in his paper No. 28 and we would like to hear more from him.

With these few words, I beg to present my paper before you and it is now for you to decide whether the suggestions contained in my paper are acceptable to you or not.

The following paper was next taken as read:—

Paper No. 27.

DESIGN OF HIGHWAY BRIDGES.

THE NECESSITY FOR AN ALL-INDIA SPECIFICATION

BY

W. A. RADICE, B.A., A.M.I.C.E.

G. WILSON, B.Sc., A.M.I.C.E.

AND

P. F. S. WARREN, B.A., A.M.I.C.E.

India's need of road bridges.—Road transport in India is developing rapidly and there is an urgent and general need for the construction of new roads and the improvement of existing ones, which in nearly every case involves the construction of bridges.

Besides the requirements of new roads, there are still many existing roads of major importance inadequately provided with bridges; and since the natural tendency has always been to build the cheaper bridges first, the primary requirements include a considerable number of major bridges which give scope for engineering skill of the highest order. In many places permanent bridges are needed to replace causeways, ferries and the temporary bridges sometimes used in conjunction with them; and since these represent recurrent annual expenditure, a permanent bridge in such cases often offers

a direct, tangible, economic advantage besides the normal advantages of convenience, greater speed of transport and larger permissible loading of vehicles.

2. In most provinces there are a number of projects for bridges that have been waiting in pigeon-holes for many years for want of finance, and the retardation of the development of road traffic consequent upon this limitation of resources makes it of the utmost importance that every rupee spent should be laid out to the best advantage. It is generally recognised now-a-days that wise spending in such large-scale affairs is dependent on expert planning and standardization, and the economical and efficient construction of bridges requires the services of experts who have devoted their careers to the study of the special problems involved.

3. *The necessity for standardization.*—Until comparatively modern times the construction of road bridges was in all countries left almost entirely in the hands of the local interests concerned, except in important centres or along essential arteries of national life. The result of this was that bridges were generally built solely to meet restricted local requirements, without reference to the possibilities of future development or recognition of advances in the art of construction made elsewhere. Their size depended on the needs of local traffic or the length of the local purse and the materials used were such as could be readily obtained from local sources for the cheapest outlay. But the recent expansion in the importance, volume and weight of road traffic has made the construction of road bridges a matter for national rather than local consideration; and everywhere national codes have been brought into force for the purpose of standardising the data, materials and methods of construction in order to ensure that bridges shall adequately meet the requirements of modern traffic in the most efficient and economical manner. In Britain this has been effected by the operations of the Ministry of Transport, and similar organisations exist in other western countries charged with the same object.

4. In India, the application of these principles has so far been assured only to the construction of railway bridges, which has been attained by the labours of the Railway Bridge Engineers Committee assisted by the Consulting Engineers to the Indian State Railways resulting in the creation of the Central Standards Office of the Railway Board. This has achieved two main results:—

First, all railway bridges, whether new or in replacement of old, are constructed in accordance with a definite plan which co-ordinates permanent way, axle load of vehicles and locomotives, bridge clearances, running dimensions, etc., to definite standards previously established and carefully selected to suit the needs, present and future, of each line or system of lines.

Secondly, a large number of typical spans for each of the standard loadings have been standardized, so that the full economical advantages of mass production are secured and the labour of designing bridges is reduced to a minimum and concentrated in the hands of experts.

5. In the case of road bridges, however, there is no national policy or correlating authority in India. Some provinces have evolved more or less complete specifications for bridges; others have appointed specialists, but in general the little that has been achieved is due more to local enthusiasms and personal energies than to a co-ordinated effort working on agreed lines

towards a settled goal. We still see that hard worked and sorely harassed official, the District Board Engineer, entrusted with the task of designing bridges, frequently of major importance.

6. The science of bridge design and erection, and even the materials of construction themselves, are constantly developing and improving throughout the world, and even specialists find it difficult to keep abreast of progress. Thus, simply for lack of co-ordinated information, the modern engineering resources of the country are frequently not made use of. On the one hand, bridges are still being built to out-of-date designs, of poor materials and inadequate capacity; while on the other, the application of too rigid and too circumscribed local specifications produces bridges which, though of a more modern type, are often unsatisfactory and uneconomical.

7. Such important items as loadings, width of roadway, allowance for impact, and permissible stresses vary from province to province and sometimes even in the same province. Decentralization has been carried to such a pitch that cases occur of different bridges in a relatively restricted area being designed and constructed simultaneously by such differing bodies as an Improvement Trust, a Municipality, a Railway, a District Board and the Corps of Royal Engineers, all to different standards depending on the leanings of officers who are constantly changing. It is no exception along an arterial road, on stretches of which the axle-loads and nature of traffic are limited by one authority, to find successive bridges constructed by other authorities of varying widths, varying standards of loading and varying clearances.

8. This Paper is therefore directed towards an examination of the economics of different types of road bridge construction to suit different conditions, to a review of the various specifications in use in India, and towards a plea for universally applicable Indian Bridge Rules, rigid in the loadings and stresses they prescribe but all-embracing in the materials and methods they include. Timber, steel, concrete and stone; girders, arches and suspension bridges; all have their proper place in bridge construction, and only by the proper selection of each in conformity with well-established standards can real uniformity, efficiency and economy be attained.

9. *Scope of standardization.*—It is perhaps necessary at this point to anticipate the possible criticism that among so great a variety of types of bridges any uniformity is impossible; but it is in no way desired to suggest that standardization of designs should at first go further than standardization of specifications, though this might in time be followed by the production of standard designs for the more common spans for certain materials and certain standards of loading. This procedure would greatly facilitate the work of purchasing authorities in preparing schemes, estimates and tender documents, and would ultimately cheapen construction in ordinary cases, without in any way restricting initiative and progress. While on this subject, the following example of the abuse of the word "uniformity" is given, as it is not without humour and shows up the pit-falls of any attempt at over-standardisation. The Engineer of a certain local authority, who always calls for tenders for steel bridges on competitive designs by contractors, several times rejected designs for Warren-truss spans on the ground that he preferred to have all spans in his district of the Pratt-trust type for the sake of uniformity—this although probably no two of his Pratt-truss bridges were to the same design!

10. *Economic Span.*—Before examining the various types of bridges, the question of the economic span for any particular case may well receive attention, as a clear perception of the basic principle underlying its choice will lead to a more correct appreciation of the various types of bridges and their proper spheres. If a bridge is to be constructed of a certain length and there are no restrictions as to the lengths of the spans or positions of the piers, then the most economical span is such that the erected cost of the main girders of one span is equal to the cost of one pier. This is a well known principle, but one too often entirely misinterpreted in practice. Very often the cost of a span including floor system and bracing is compared with the cost of a pier. This results in the choice of a span length too small for economy. The cost of the average pier should equal the erected cost only of the main girders of the span, not of the whole span. Frequently the bridge expert can effect a saving of 10 to 40 per cent. in a bridge project by redesigning it with the economic span instead of an arbitrary one. If there are no restrictions, such as minimum spans specified for navigational purposes, the economic span will obviously depend on the height from base of foundation to top of pier, and the first step in preparing a project is to design a minimum pier for the situation and estimate its cost. If this pier is suitable for the span the main girders of which cost the same as the pier, then the economic span is found. If not, then it is necessary to design another pier and proceed by trial and error until agreement is reached. It may also be necessary to consider different types of bridges, and it is here that the expert can use his intimate knowledge of different types to advantage.

11. *Types of bridges.*—Bridges may be divided into the following types:—

Beams, Plate Girders and Trussed Girders: simple, continuous, semi-continuous (Wichert) and cantilever.

Arches and Tied Arches;

three-pinned, two-pinned, one-pinned, and hingeless. Cantilever arches are included in this category.

Suspension Bridges;

stiffened and unstiffened.

Or we may classify the types of bridges according to the spans for which they are generally suited:—

Up to 10 feet—

Steel trough plates.

Reinforced concrete slabs.

Stone or brick arches.

10 feet to 40 feet—

Rolled steel beams.

Reinforced concrete beams or arches.

Stone or brick arches.

40 feet to 100 feet—

Steel plate girders.

Low truss steel girders.

Reinforced concrete arches.

100 feet to 500 feet—

High truss steel girders.

Steel arches.

Reinforced concrete arches.

Steel suspension bridges (for light loads only, unstiffened or partially stiffened).

Over 500 feet—

Steel arches.

Steel cantilevers.

Steel suspension bridges (fully stiffened).

12. Cantilevers, semi-continuous and continuous trusses have not been separately mentioned for the smaller spans, but they may be used with advantage in many cases. In the case of a road bridge of a large number of spans it is almost always advantageous to extend the ends of alternate spans a short distance beyond the piers and to suspend smaller spans from the cantilever ends: this applies equally to beams, plate girders, and trussed bridges. In the case of trussed girders of span over about 200 feet it is still more advantageous to make the spans continuous, if the foundations are rigid, or semi-continuous if there is any danger of settlement of the piers. The semi-continuous truss has recently been invented and patented by an American, Mr. E. M. Wichert, and is a continuous truss, which, thanks to an ingenious rhomboidal framework over each pier, is not only statically determinate but is also unaffected by even considerable settlements of piers. Steel arches and cantilevers can be built up to about 2,000 feet span, but for road bridges of over 1,000 feet span in most normal locations a suspension bridge will be more economical. Suspension bridges can now be designed for spans up to about 5,000 feet in length, and where traffic density is great such long spans are financially feasible.

13. *Piers and foundations.*—As has already been stated, the economic span depends on the cost of the pier. Any pier may be divided into two constituent parts, the pier-shaft and the foundation: broadly speaking, these are respectively the parts above and below ground level or low water level. Pier shafts may be of stone masonry, brick masonry, plain concrete, reinforced concrete, or steel trestle construction. Piers may be founded on bed-rock, on wells sunk by open dredging or by the pneumatic process, on steel screw piles, on pre-cast concrete piles or on one of the many types of concrete piles cast *in situ*.

A foundation on bed rock calls for no comment except that proper provision must be made for transmitting over-turning forces to the rock or absorbing them in a foundation block, or blocks, of sufficient weight to provide a margin of safety.

14. Next in order of cheapness are pile foundations, which are suitable for depths up to about 100 feet below ground or low water, provided the depth from low water level to the level of maximum scour is not excessive. If this depth is too great, excessive bending moments will be caused in the piles by lateral forces and it is very expensive to brace piles below low water level and almost impossible below normal bed level. If concrete piles of a shell-less type cast *in situ* are used in water-bearing strata, it is essential that the concrete be strongly compacted and strongly rammed out against the surrounding soil with a heavy monkey as it is placed, otherwise there is a grave danger,—in fact almost a certainty,—that the subsoil water will dissolve out and wash away the cement before the concrete sets and the result will be a "sand" pile, constituting a likely cause of disaster to the bridge.

For foundations of large size or great depth, and where scour is too great to permit of the use of piles, wells are necessary.

15. *Requirements of a specification for bridgework.*—A specification for bridges must specify the live loads to be provided for in designing all parts of the structure, and must cover the quality, working stresses and workmanship of all materials used in the spans, piers and foundations. The sections of such a specification, and the main heads of its clauses, should therefore comprise the following:—

A. Loads.

(1) Live loads and their classification.

(2) Impact factor.

(3) Wind pressure.

(4) Longitudinal forces, curvature and temperature effect.

(5) Deformation stresses and secondary stresses.

(6) Relief of stress and combined stresses.

(7) Anchorage to foundations.

B. Steel Bridges.

(1) Specification for structural steel.

(2) Specification for high tensile steel.

(3) Stresses in structural steel, high tensile steel, rollers, cast steel, wrought iron, cast iron, copper alloy bearings, and under bed plates.

(4) Alternating stresses.

(5) Frictional co-efficients for expansion bearings, effective spans and lengths, depths and cross sectional areas, and minimum sections.

(6) Details of construction, latticing, rivetting, stiffeners and connections.

(7) Welding-stresses in welds and details of construction.

(8) Workmanship in the shops.

(9) Workmanship at site and supervision.

C. *Reinforced Concrete Bridges.*

(1) Specification for Portland cement.
(2) Specification for rapid hardening cement.
(3) Specification for aluminous cement.
(4) Specification for reinforcing steel.
(5) Specification for fine and coarse aggregate.
(6) Specification for water.
(7) Specification for formwork.
(8) Principles and assumptions.
(9) Stresses in concrete.
(10) Stresses in reinforcing steel.
(11) Bond stress, anchorage, combined compression and bending stresses, tension in concrete.
(12) Frictional co-efficients for expansion bearings.
(13) Effective spans and lengths, effective depths of slabs and beams, minimum breadths of beams, flanges of Tee beams, effective area of columns, tension members.
(14) *Details of construction*:—cover, bar spacing, minimum reinforcement, bends, joints, bending and placing.
(15) *Site work*:—supervision, proportions of mixed materials, measuring materials, plant and tools, depositing concrete, stops and junctions, removal of forms, protection of new concrete, face dressing.
(16) *Tests*:—proportions, slump test, strength tests and loading tests.

D. *Masonry.*

(1) First class masonry.
(2) Second class masonry.
(3) Mortar.
(4) Pointing.
(5) Stresses in masonry.
(6) Workmanship.

E. *Brickwork.*

(1) Specification for bricks.
(2) Cement mortar.
(3) Lime mortar.
(4) Bond.
(5) Pointing.
(6) Stresses in brickwork.
(7) Workmanship.

F. *Caissons sunk by open dredging.*

G. *Caissons sunk by the pneumatic process.*

Regulations for the employment of labour under compressed air specifying hours of work and periods of decompression for various pressures.

H. Concrete Piles.

I. Steel Piles and Screws.

J. Cast iron cylinder piles and screws.

K. Sheet piling.

16. *Comparison of existing specifications.*—There is actually no one specification or set of specifications covering all the foregoing points in a manner suitable to Indian conditions, and the specifications at present in use in various parts of India will now be discussed. These comprise:—

British Standard Specification No. 153.

Indian Railway Board Bridge Rules.

Madras P. W. D. Specification.

Bombay P. W. D. Specification.

Draft Bengal P. W. D. Specification.

Central Provinces P. W. D. Specification.

Assam P. W. D. Specification.

It will be convenient to take each heading of the model specification outlined above, and to consider the rulings of the various existing specifications bearing on it.

A. LOADS.

17. **A (1) Live Loads.** *British Standard.*—The minimum recommended for roads in Great Britain is 15 units. Impact factor:—

$$I = \frac{80}{90 + \frac{n+1}{2} L} \quad \text{Subject to a Maximum of 70 per cent.}$$

Indian Railway Board Bridge Rules "B" class loading.—10 British standard units diminishing from 7 at 80 feet to 5 at 300 feet. Impact standard units diminishing from 10 at 80 feet to 6 at 300 feet. Impact factor:—

$$I = \tfrac{1}{2} \times \frac{65}{45 + L} \quad \text{Subject to a Maximum of 50 per cent.}$$

Indian Railway Board Bridge Rules "C" class loading.—7 British standard units for spans up to 80 feet, then a sliding scale of British standard units diminishing from 7 at 80 feet to 5 at 300 feet. Impact factor:—

As for "B" class.

Bombay P. W. D.—12 British standard units. Impact factor:—
50 per cent.

Madras P. W. D. "B" class loading.—One road roller weighing 12·17 tons in working trim together with one lorry weighing 11 tons when fully loaded, and 80 pounds per square foot on the area of roadway unoccupied by the roller and lorry. Impact factor:—

80 per cent on roller and lorry only.

Bengal P. W. D.—8 1/2 British standard units. Impact factor:—
This varies for different types of bridge as is shewn on diagram No. 2.

Central Provinces P. W. D.—One road roller weighing 10 tons in working trim, and 85 pounds per square foot on the area of roadway unoccupied by the roller. Impact factor:—

50 per cent for reinforced concrete slab deck.

33 per cent for cross girders.

25 per cent for main girders,

all on roller only.

Assam P. W. D.—One road roller weighing 10 tons in working trim and 80 pounds per square foot on the area of roadway unoccupied by the roller. Impact factor:—

25 per cent on roller only.

18. It might appear at first that the ideal live loading for the light class was the Madras P. W. D. "B" class loading, but further consideration will show that this is not the case. Loadings of this type, suffer from two main disabilities: the loading is too heavy in the case of the long spans, as it is most improbable that a bridge in a country district will be packed with a dense crowd from end to end, and the impact allowance is unscientific and, in the case of the shorter spans, insufficient. The Central Provinces P. W. D. specification is better in this respect, but still not ideal.

Similarly, a loading which is merely a multiple of the British Standard Unit loading has the disadvantage of being too heavy on the longer spans because it does not take account of the infrequency of heavy traffic units. For this reason the Indian Railway Board Bridge Rules for bridges over railways seem to provide the more suitable loadings. Both their "B" and "C" class loadings start with a uniform multiple of British standard units for spans up to 80 feet and then these are diminished on a sliding scale to a considerably smaller multiple at 300 feet span.

19. A (2) **Impact Factor.**—The total load applied to a bridge by the live loads is augmented by their dynamic effects, and the impact factor may be described as the bridge designer's ready measure of the appropriate increment. A mathematically beautiful and exact method of computing these dynamic effects has been evolved by Professor Inglis, but it has not yet been possible to simplify it sufficiently for use in everyday bridge design.

20. The impact factors prescribed by the various specifications at present in use in India have been set out above along with the live loads to which they apply, and it is seen that they vary from simple percentage increments to more or less complex formulæ. The former are purely empirical and take no account of the loaded length of the bridge; but the formulæ in general use are all empirical curves fitted as closely as possible to experimental results, and have the more rational effect of making the impact factor vary with the loaded length. That is the total effect of the live load on any particular bridge member equals the static effect multiplied by $(1+I)$, where I is the impact factor deduced from a formula $I=F(L)$ and L is the length of that part of the bridge which must be loaded to produce the greatest stress in the member in question.

21. To illustrate this point let us consider all the members in a bridge of 120 feet span having six panels of 20 feet as sketched on diagram No. 1:—

For a Stringer . . .	L=the panel length=20 Feet.
For a Cross Girder . .	L=two panel lengths=40 Feet.
For the End Posts and Chords	L=the span length=120 Feet.
For tension in $U_1 L_2$, . .	L=96 Feet.
For compression in $U_1 L_2$, .	L=24 Feet.
For compression in $L_2 U_3$, .	L=72 Feet.
For tension in $L_2 U_3$ . .	L=48 Feet.
For $U_1 L_1$, $U_3 L_3$ and $U_5 L_5$	L=two panel lengths=40 Feet.

It will thus be seen that if the impact factor were neglected, the floor system and web members would be subject to greater unit stresses than the chords; or alternatively, that if a uniform impact factor were applied having no relation to the loaded length, the chords would be unnecessarily heavy compared with the floor system. By applying an impact factor in a rational manner the bridge designer aims at making all parts of the bridge equally effective.

22. The most generally accepted formulæ for impact factor for steel road bridges are:—

British Standard Specification No. 153.

$$I = \frac{80}{90 + \frac{n+1}{2} L} \quad \text{with a limit of } 0{\cdot}70.$$

where L = the loaded length as defined above,

and n = the number of traffic lanes.

Indian Railway Board Bridge Rules.

$$I = \tfrac{1}{2} \times \frac{65}{45+L} \quad \text{with a limit of } 0{\cdot}50.$$

where L= the loaded length as defined above.

Waddell's Text Book.

$$I = \frac{100}{nL+200}$$

where L = the loaded length as defined above

and n = width of roadway in feet divided by 20.

23. For reinforced concrete bridges it is generally recognised that there should be no reduction of the impact factor applicable to steel bridges, except in the case of arches with an earth cushion at least 3 feet thick at the crown, in which case it is sometimes considered that impact may be neglected. The impact factors given above are specified for steel bridges, except that of Waddell which is also applied by him to the design of reinforced concrete bridges. Arrol's reinforced concrete handbook, which includes a compendium specification culled from the best practice, recommends that the B. S. S. impact factor be used for concrete bridges. The Indian Railway Board Bridge Rules, however, at present prescribe a higher impact factor for reinforced concrete bridges than steel bridges.

24. **Combined effect of load and impact.**—The design of a bridge span depends on the sum of the live load and impact, and it is convenient to express this in the form of an equivalent uniformly distributed load. The graphs plotted on diagram No. 2 show the total equivalent uniformly distributed loads per square foot of floor area for the following cases:—

(1) 8 1/2 British standard units with impact according to B. S. S. No. 153.

(2) & (3) Indian Railway Board Bridge Rules, "B" and "C" class loadings.

(4), (5), (6), (7), (8) and (9) 8 1/2 British standard units with impact according to the Bengal P. W. D. proposals.

(10) Madras P. W. D. "B" class loading.

These graphs bring out all the points already discussed, and incidentally suggest that the proposals of the Bengal P. W. D. concerning impact are not only somewhat arbitrary and complicated but are contrary to the consensus of opinion of leading authorities in treating reinforced concrete more favourably than steel.

25. For purposes of comparison with the standards adopted in other countries graphs are plotted on diagram No. 3 showing the relationship between the Indian Railway Board "B" and "C" class loadings, the French standard loading, and the American standard "AA", "A" and "B" class loadings.

26. Apart from the technical considerations involved, the loading and impact factor adopted for design largely influence costs, and the following table shews the approximate variations in cost of steelwork for bridges designed for the loadings set out in diagram No. 2.

Table of comparative costs of Steelwork for a Bridge with 18 foot Roadway.

Span (in feet).	Loading.				
	Ry. Board "B" Class.	Ry. Board "C" Class.	8 1/2 B. S. Units B. S. S.	8 1/2 B. S. Unit Bengal P. W. D.	Madras P. W. D. "B" Class.
	Rs.	Rs.	Rs.	Rs.	Rs.
60 . .	9,000	8,000	8,250	9,000	7,500
100 . . .	18,400	16,900	18,700	19,300	16,600
150 . . .	34,200	31,200	34,600	36,800	31,600
200 . . .	55,000	50,000	57,500	65,500	52,500
300 . . .	1,14,000	99,000	1,16,500	1,28,000	1,08,500

27. It will be seen from this table that the Indian Railway Board "C" class loading could be substituted for the Madras P. W. D. "B" class loading with only a small increase in cost for short spans and a saving for spans 150 ft. and over; but the Bengal P. W. D. *proposals* would result in considerably higher costs than either the British standard for the same loading or the Indian Railway Board "B" class loading.

28. Of existing and readily available standards the Indian Railway Board "B" and "C" class loadings appear to be the most suitable for general adoption. These carry the additional advantage that complete tables of equivalent uniformly distributed loads for the design of all spans up to 300 feet have already been published, which greatly facilitate the preparation and checking of designs.

29. A. (3) **Wind pressure.**—30 pounds per square foot of exposed area on the loaded bridge and 50 pounds per square foot on the unloaded bridge are specified both by British Standard Specification No. 153 and the Indian Railway Board Rules. The Madras P. W. D. specify either the same as the British Standard Specification, or alternatively, for bridges of under 300 feet span, 150 pounds per lineal foot of bridge on the unloaded chord and 300 pounds per lineal foot of bridge on the loaded chord. This alternative has much to commend it by reason of the simplicity of its application in design.

30. A (4) **Longitudinal Forces.**—These are specified in the case of railway bridges to provide for tractive effort and breaking effects. Such effects are likely to be small in road bridges and it is suggested that the only longitudinal force it is necessary to provide for is that due to diagonal wind, and that this could well be covered by specifying a longitudinal force on the span equal to one half of the normal wind load.

31. A (4), (3), (6) and (7) **Curvature, Temperature Effect, Deformation Stresses, Secondary Stresses, Relief of Stress Combined Stresses and Anchorage.**—These are all well provided for both in the British Standard specification and in the Indian Railway Board Bridge Rules.

B:—STEEL BRIDGES.

32. B (1) and (2) **Specifications for Structural and High Tensile Steel.**—A reference to the current British Standard or Indian Railway Standard Specifications would be sufficient.

33. B. (3) **Stresses in Materials.**—Most Provinces follow the British Standard Specification, which is identical with the Indian Railway Board Bridge Rules in this respect. The Madras P. W. D. specifies lower working stresses, but takes no account of wind loads unless they exceed 25 per cent. of the live *plus* dead load in the member. This is quite a good rule where short span bridges are concerned, as it makes for sturdiness, but it results in waste of metal in the web members and bracing of long spans, and it would be illogical to specify different working stresses for different spans.

34. **B (4) Alternating Stresses.**—The British Standard Specification and Indian Railway Board Bridge Rules both specify that members subject to alternating stresses shall be proportioned for tension and compression separately and that half the smaller gross area shall be added to the larger gross area to give the total section necessary. Both these specifications were drafted primarily for railway bridges of up to 800 feet span, and in such bridges there are reversals of stress in the web members every time a train crosses the bridge.

35. It is, however, the opinion of leading Bridge Engineers in America that such a clause should find no place in modern specifications for long span bridges, whether railway or road. It would therefore appear unnecessarily burdensome to promulgate this clause for road bridges, except as a corrective for light and vibratory web members in short spans; and it is suggested that this could well be covered, and the burdening of longer spans avoided by a clause reading somewhat as follows:—

> "*Alternating Stresses.*—In the case of a member subject to alternating stresses if the 1/r ratio is greater than 60 the larger load shall have added to it a percentage p of the smaller load such that p=1/r—60; and the member shall be proportioned to carry this total load and shall be designed as a stiff member to provide for the compression stress."

36. **B (5) Frictional co-efficients, effective spans, lengths and cross-sectional areas.**—The British Standard Specification, the Indian Railway Board Bridge Rules and the Madras P. W. D. Specification are in accord on all these points, with the exception of the effective cross sectional area of tension members.

37. In the case of tension members, the British Standard Specification makes no direct provision for deduction of area on account of holes not in the actual plane of the cross-section considered. The Indian Railway Board Bridge Rules make provision for this by two alternative methods, one of which is that given on page 295 of Waddell's "Bridge Engineering". The Madras P. W. D. Specification takes account of all holes within 4 inches of the plane of the cross-section considered by deducting from the sectional area a proportion of the area of each hole equal to A (1—p/4), where A is the area of the hole and p is its perpendicular distance from the plane of the cross-section.

38. The Madras P. W. D. formula has the merit of simplicity, but results in excessive deductions if the gauge width between lines of holes is small in relation to the pitch and insufficient deductions if it is large. Waddell's method appears to be the most scientific and is very easy to apply, as it is given in the form of a graph.

39. **B (6) Details of Construction.**—The British Standard Specification, the Indian Railway Board Bridge Rules and the Madras P. W. D. Specification are in general agreement, and comment is unnecessary.

40. **B (7) Welding.**—The Indian Railway Board Bridge Rules state that welding may be employed for the complete construction of highway bridges and contain a number of provisions for welding. This is a proper

recognition of the place welding has already obtained in structural work and of its undoubtedly increasing importance in the future.

It is believed that further provisions for welding are about to be published in Report No. 15 of the Bridge Standards Committee of the Railway Board, and it is essential that any future bridge specification should provide for welding and that this section should be kept up-to-date and revised periodically by a committee of experts.

41. **B (8) and (9), Workmanship and supervision.**—The importance of good workmanship and expert supervision cannot be too highly stressed. As is well known, the working stresses in structural steel have been increased in recent years from 7½ tons per square inch in tension first to 8 and then to 9 tons per square inch, but it is not generally realized that this is not so much due to improvement in the quality of the material as to revolutionary changes in the methods of fabrication, introduced by the leading bridge constructors in England and India and involving standards of accuracy and workmanship that would be considered good in any heavy machine shop. India can be proud in the knowledge that steelwork can be fabricated in the country to a standard that is unbeatable anywhere and that India has taken a leading part in the setting up of this higher standard.

42. It is obviously of the utmost importance that, as the higher working stresses permitted by this improved workmanship are specified, the specifications should rigidly enforce the provision of the necessary standard of workmanship, and it is inadmissible that modern structural work should be fabricated by bazar standards. The modern structural shop thinks in thousandths of an inch.

43. These recent refinements in fabrication have led to refinements in the erection of large spans. The method of pre-stressing large spans during erection to minimize secondary stresses normally co-existent with full load has recently been introduced and is a noteworthy advance in the technique of bridge construction. Where this method is used it permits a considerable economy of metal in long span bridges.

44. Experienced supervision of site erection is also most necessary and proper provision should always be made for this: no bridge of any magnitude should be erected without the supervision of a qualified structural engineer.

C.—REINFORCED CONCRETE BRIDGES.

45. **C (1) to (7). Materials.**—A number of British Standard Specifications for the materials used in reinforced concrete construction already exist, and more are in course of preparation. These might well be adopted for general use in India.

46. **C (8) to (16). Design, Workmanship and Supervision.**—There is no complete British or Indian specification for Reinforced Concrete Bridges yet issued, though it is believed that the British Standards Institution and the Indian Railway Board both have the preparation of a specification in hand.

47. The foregoing remarks about steel bridges are intended as suggestions for the rational co-ordination of existing specifications, and little comment can be made on specifications for reinforced concrete bridges until these are published. A number of main headings have, however, been indicated as requiring consideration, and for the purpose of this Paper those concerning working stresses, workmanship and supervision may with advantage be slightly amplified.

48. It appears important that the main working stresses should be specified as percentages of the ultimate strength of the materials to be used and that proper provision should be made to ensure that the actual materials used do not fall below the standard assumed in design. It is also important that the various stresses specified should be harmoniously related to one another, and the effects of new structural materials must not be overlooked: for example, the overlaps must be greater if high tensile reinforcement is used, as otherwise the allowable bond stress might be exceeded.

49. The quality of reinforced concrete is determined entirely by the workmanship at site, and it is essential, especially in this country where the educational level and sense of responsibility of the labourer is low, that no reinforced concrete bridge should be constructed except under the direct and wholetime supervision of a fully qualified and experienced Engineer. The specification should insist on this.

D. & E.:—BRICKWORK AND MASONRY.

50. There are various Provincial specifications for these items, but these specifications need to be co-ordinated and provision made for the inclusion of all the important types of building material used in India for bridge piers.

F. & G.:—CAISSONS.

51. It is important that there should be no chance of failure of a caisson during sinking, when it is subjected to strains that it will not have to bear when in its finished state. A few general regulations should cover this. Regulations are also required for the employment of labour under compressed air. Reference may be made to an excellent article on this subject by Sir Henry Japp in the March, 1935 number of "The Structural Engineer".

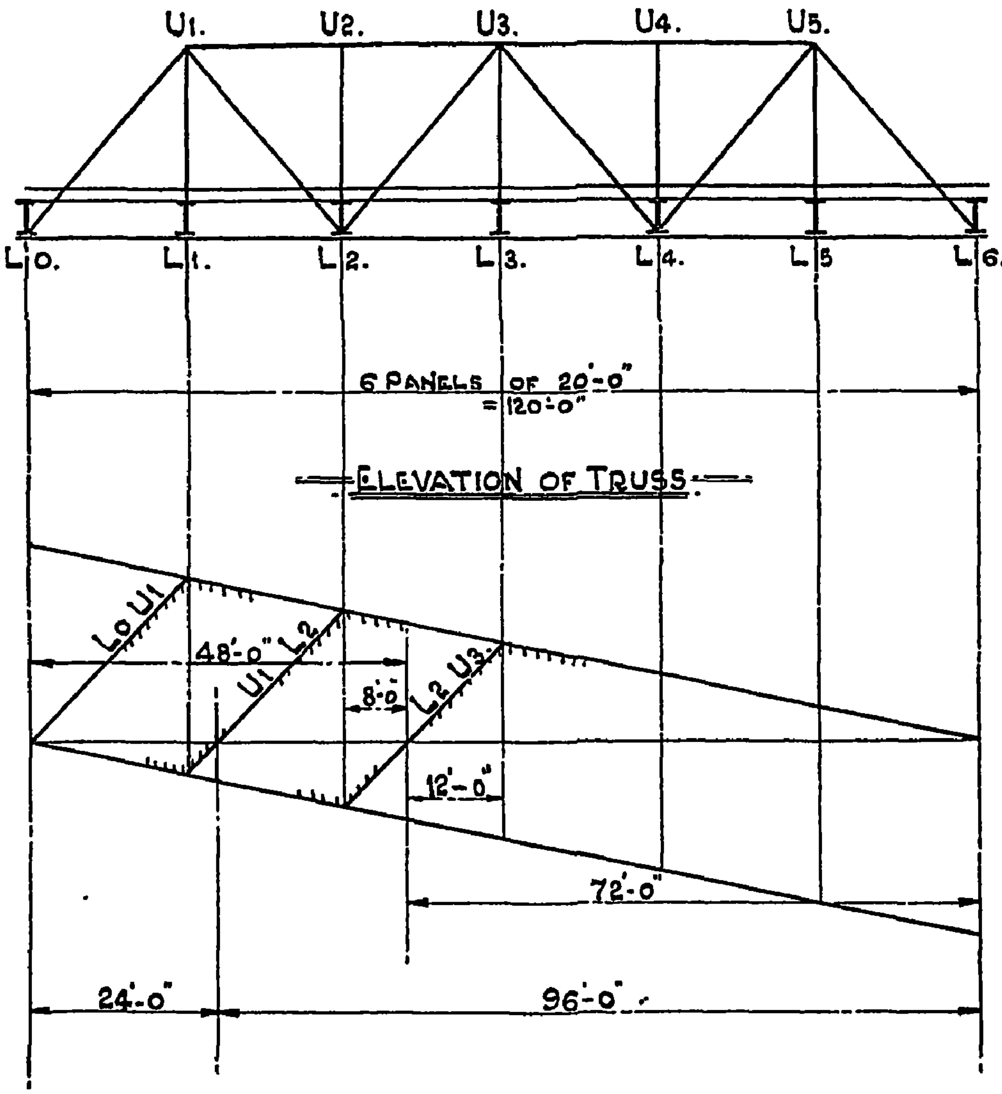
H., I., J. & K.—PILING.

52. The specifications applicable to steel and reinforced concrete superstructures may equally be applied to steel and reinforced concrete piling, but it is essential in the case of reinforced concrete piles cast *in situ* that there should be no possible doubt as to the quality and continuity of the concrete.

CONCLUSION.

53. In conclusion, it is felt that an apology is necessary for the very superficial treatment that has been accorded to a most important subject, but its scope makes fuller treatment impossible within the limitations of a Paper of this nature. It has been considered preferable to touch on as many aspects of the subject as possible rather than to concentrate on a few, since the object of the Paper is not to dictate suggestions, but to stimulate discussion of action directed towards planned scientific advancement in the art of bridge building in this country and to indicate the very numerous lines along which co-ordination of thought and effort are necessary.

The work of preparing this Paper will be well rewarded if, as a result, this Congress should decide that action is desirable and can create the necessary machinery for giving it effect.



INFLUENCE LINE DIAGRAM.
FOR WEB MEMBERS.

DIAGRAM No. 1.

Mr. W. A. Radice: Chairman and Gentlemen, Before introducing my paper I should like to make one little correction in the regroupment list of these papers. The three Authors have been there described as belonging to Jessop & Co. Ltd., Calcutta. Mr. Warren is one of the Directors of that Firm but Mr. Wilson and myself have been for many years employed by Messrs. Braithwaite & Co. (India) Ltd., and are now members of The Braithwaite Burn & Jessop Construction Company Limited.

In this paper, we want to represent the views of fabricators of steel bridges, as we have spent our working life in India in designing, manufacturing and erecting them. We do not pretend to know much about concrete, we have only studied it in connection with our work.

As our work consists in realising the specifications drafted and accepted by the Government Departments, we are in a good position to ascertain what each item and paragraph of a specification costs, because we have to implement them. It is this experience that makes us feel very keenly that a standard specification for India should be adopted.

Our purpose in presenting this paper has been not so much to make recommendations or discuss the various points such as those which specifications should cover, but rather to present the reasons why a standard universal specification should exist, and also to outline very briefly the field which we think it should cover.

A thing that must strike everybody who has read Mr. Banerjee's paper where he has very patiently gathered together all the specifications for Live Loads & Impact that already are in use in India, is that there are many and various bridges that have been built to each of these specifications—a good many by the authors of this paper—and yet although the specifications differ, the loadings and impact allowances differ, costs for the same spans differ,—these bridges are all standing up. (Laughter). So either some of the specifications are extravagant or some impose on the bridges stresses which are greater than they should be. I think that is the best reason that I could advance for a standard universal specification.

There is also another important advantage from the manufacturer's point of view (an economic advantage, which is passed on to the customer ultimately) in having a standard specification. In the last 10 years. bridge makers throughout the world have developed an improved method of fabricating steel bridges and that is what we call "The 100 per cent. interchangeable method". By this method the component pieces of a bridge are turned out just as pieces of "Meccano", with extreme accuracy and cheaper than could be done by any other method. But to attain this there must be repetition. Once a set of jigs has been made for a certain span, to a given loading, and to a given design, the same jigs will reproduce spans with equal accuracy—not only 10, 20 or 30 spans but any number. It is a fact that by using these methods the two thousandth span will be just as accurate as the first one. Mr. Everall, a great friend of mine, who was the Deputy Chief Engineer for Bridges on the North Western Railway, has estimated that the saving on erection costs in a bridge made entirely interchangeable, amounts to about Rs. 15 to Rs. 20 per ton. That is another direct economic advantage to the buyer.

There is also a third indirect advantage and that is that with such accuracy, one can make the various component parts of a bridge of such

lengths that when the bridge is put together, each member has had forced into it a reverse stress opposite in sign to the secondary stresses which are induced in the member when the span gets distorted under load. The result is that when the span is loaded and the camber is taken out, *i.e.*, the bridge becomes flat, as shown in the drawings, the reverse stresses are taken out and we can ensure that the span carries only the primary stresses imposed by the load and its own weight and is relieved of all secondary effects caused to distortion under load. That has an important economic effect because it permits of the use of increased working stresses. This is the reason why the British Standard Specification for the design of Bridges has been revised, permitting a working stress of 9 tons per square inch (instead of 8 tons as previously specified) in tension members and similar augmentations for members in compression.

The following paper was next taken as read:—

Paper No. 28.

PERMISSIBLE STRESSES IN CONCRETE BRIDGE DESIGN

By

W. J. Turnbull, B.Sc., M.Inst.C.E.

I may possibly be criticised for making the introduction to the actual subject matter of this paper somewhat lengthy, but this I have thought advisable in order to give some of the delegates a more scientific conception of the material which, in combination with portland cement, forms concrete.

2. Present day economic conditions demand the elimination of waste and the efficient utilization of all materials. Owing to the casual methods of making concrete in India no provision is made in the commonly accepted design practice for concrete having strength higher than about 2,500 pounds per square inch at the age of 28 days. In the past thirty years however there has been a remarkable improvement in the quality of portland cement, and this, combined with the knowledge that has been gained as to the effect of the various factors in making concrete, now makes it possible to proportion and use concrete of a much higher strength. Higher strengths are easily obtained, but if they are to be depended upon and used in design, it is essential that each operation in the making and placing of concrete be properly controlled. Only by such control can the material be used to the best advantage, and economy thereby obtained.

3. The basic principles of making cement concrete are the same regardless of the type of structure under consideration. Concrete is economical in that it can be designed to meet the varying requirements needed in an individual structure which may be great or normal strength, a definite strength at a fixed time, or impermeability. Resistance to wear or severe exposure may be the governing factors for design. Any one or a combination of these qualities may be required in the same structure.

4. It is customary to express the structural value of matured concrete in terms of its compressive strength. The other characteristics such as impermeability, resistance to exposure and wear, are to a large extent, dependent upon the compressive strength. When it is not accompanied by

watertightness, concrete of high compressive strength may lead to a false security in the quality of the structure.

5. The requirements for a successful concrete bridge are that the concrete must have sufficient strength to carry the loads imposed. The concrete must be durable under the conditions of exposure to which it will be subjected. The concrete must be produced economically in comparison with other materials of equal constructional value. The major factors affecting the durability of concrete, particularly in bridge structures, are three:—(*a*) Quality of the cement; (*b*) Nature of the aggregates; and (*c*) Watertightness.

(*a*) Cement, being the binding medium, is important in securing durable watertight and weather resistant concrete. The British Standard Specifications have been revised on several occasions as a result of experience and experiment in order to protect the user of cement. Portland cement of Indian manufacture meeting these requirements can be depended upon to make concrete having the desired properties.

(*b*) As aggregates form nearly three-quarters of the mass of matured concrete, they are therefore important in the production of durable structures. Aggregates which will rapidly disintegrate under the influence of the weather, will not endure indefinitely in a concrete structure, even with the protection given by the cement paste surrounding them.

(*c*) It is recognised that the most important requirement for concrete in order that it shall meet the destructive effects of weathering, is watertightness. Concrete behaves as do rocks under exposure. When its composition is such that water may penetrate, it is susceptible to the disintegration caused by the expansion and contraction of entrapped moisture in freezing and thawing, and is also susceptible to the solvent action of percolating water. Research and experience indicate that the more watertight the concrete, the greater the resistance to these destructive elements. In reinforced concrete especially, the penetration of moisture through porous concrete affects the steel, causing rust, and the subsequent swelling destroys the concrete.

6. Briefly the requirements for watertight concrete are: durable and impervious aggregates thoroughly incorporated in a cement-water paste which is in itself also impervious. The simple conception of the cementing medium of concrete as a paste will assist in giving a clearer idea of how to attain watertightness. This medium consists of cement and water which changes into a new material through the chemical reactions during setting and hardening. It is through the properties of this cementing medium that those of concrete are controlled. Regardless of the nature of the aggregate or combinations, strong and durable concrete cannot be made without a strong cementing medium, nor can impervious concrete be produced without a cementing medium which is in itself watertight. The conception of concrete, therefore, is a study firstly of the properties of the cement-water-paste, and secondly of the combinations of aggregates which are most desirable for use with a given paste.

7. *The Water-Cement Ratio.*—The chief factor in the quality of the cement paste, and consequently the quality of the concrete is the relative proportion of cement and water, that is, the water-cement ratio. If a thin watery paste is used, the resulting concrete will be weak and porous, while on the other hand, if a paste with low water content is used, the resulting concrete will be strong and highly resistant to the penetration of water.

Complete hydration of a measured quantity of cement can be accomplished by an amount of water that would not be sufficient to produce a material plastic enough to place: therefore, when aggregates are mixed with the paste, it is necessary to use additional water to produce workability.

8. It can be appreciated therefore that water which does not enter into combination with the cement remains within the paste, and the space it occupies will become air voids when the water evaporates. The larger these voids, the more passages there will be for the water which may eventually come into contact with the concrete. It is of vital importance to have the requisite quality and amount of paste to produce impermeable concrete. Water passing through concrete must find its way between the aggregate particles and therefore through the cement paste, and if the entire space is not filled with the paste, there is little to resist the passage of water. To be certain that the space between the aggregate particles is completely filled, it is essential that the mixture be of a plastic consistency so that the material can be worked readily into forms and thoroughly incorporate or surround the reinforcement.

9. This plastic consistency is produced by having sufficient paste of such a consistency as to actually float the aggregate particles, otherwise the concrete will be harsh and will require the most careful placing and supervision to avoid honey-combing. With a thin watery paste, segregation will take place, forming laitance at the top, and producing a non-homogeneous mass which will not be uniform in its resistance to the penetration of water.

10. Concrete may be defined as being workable and plastic when the aggregate particles are floated in the paste so that when the mixture is placed in a mould, and the mould immediately removed, the concrete will slowly change its form, or will slump, without causing segregation. A plastic consistency is between the dry, crumbly consistencies on one hand and the very fluid or water consistencies on the other. A mass that is "plastic" does not crumble, it flows sluggishly and without segregation. Unworkable concrete is not mobile and cannot be placed in a solid layer without heavy ramming, and even then may be honey-combed or have unfilled voids. We thus see that the water-cement ratio has an important influence on the watertightness of the concrete in two respects; firstly, through its influence on the imperviousness of the paste, and secondly, through its effect on the workability of concrete.

11. Professor D. A. Abrams of America after compiling data on many thousands of tests discovered that the compressive strength of concrete is also dependent upon the ratio of the mixing water to cement. The law is stated as follows:—

> *For given materials and conditions of manipulation, the strength of concrete is determined solely by the ratio of the volume of mixing water to the volume of cement so long as the mixture is plastic and workable.*

12. By means of the water-cement ratio law, the proportioning of the ingredients of concrete is the most simple and accurate method of attaining the quality desired. Under this principle, concrete is not specified in proportions such as 1-2-4 or 1-2½-5, but instead, the amount of water to be used with each bag of cement is given. Workability will be the governing factor with the specified water-cement ratio, and it will be attained by the addition or reduction of the sand or stone until a plastic mix is attained.

The specified amount of water must in all cases include the free water or moisture contained in the aggregate. The design of the mixture consists of determining by the trial batches the amounts of aggregates to use with a paste of known water-cement ratio that will produce a mixture that is plastic and workable. Workability is a factor of the water-cement ratio law, and if a mixture has not workability, the law cannot be applied.

13. Another factor which governs the quality of the finished concrete is the extent to which the chemical reactions are allowed to progress. The continuation of these reactions in portland cement requires favourable curing conditions, that is moderate temperatures and the presence of moisture. It is through curing that the internal structure of the concrete is built up to provide strength and watertightness. As concrete hardens water continues to enter into combination with the cement; therefore, it is necessary to keep the surface of the hardening concrete moist for a certain period. The longer the curing period can be maintained, the greater the improvement in the quality of the concrete. If the additional mixing water in excess of the amount required for hydration could be retained in the concrete, with no loss from evaporation of the surface, there would in all probability be enough moisture present to maintain the proper curing condition. But as this condition is usually impossible in, say, average bridge construction, the surface of the hardened mass should be kept wet immediately after the forms are removed.

14. *Engineering Supervision.*—The price of success in concrete construction is adequate and efficient supervision. The overseer on an important concrete bridge project should be chosen with care. He should have practical experience in the design and control of concrete mixtures as well as an understanding of the fundamental engineering principles involved in the construction to which he is assigned.

15. *Summary of Fundamentals of Concrete.*—The application of the principles of producing durable concrete structures can be found in the simple statement of the essentials of watertight concrete, namely, impervious, durable aggregates thoroughly incorporated in a cement paste which is in itself impervious. This imposes four requirements: firstly, the selection of a water-cement ratio that will give a paste of a high degree of impermeability; secondly, the use of aggregate of approved materials in such proportions as to obtain a plastic and workable mixture; thirdly, placing the concrete in such a manner as to insure a homogeneous mass without segregation or honeycombing; and fourthly, provision for proper protection of the structure to insure thorough curing.

16. *Unit stresses in design.*—Unit stresses used in design are based on values which represent the reaction of the interior parts of a solid body against forces tending to deform it. A practical factor of safety is also employed. In other words, stresses assumed for design are proportional to the strength of the material at a fixed time. In the case of concrete. this fixed time is usually taken as 28 days. The ultimate strength of properly made concrete is not reached at 28 days but under ideal conditions continues to increase for an indefinite time. The increase in strength after 28 days is relatively slow, but it may be assumed to be an additional factor of safety which will, to a limited extent, offset certain slight irregularities commonly incident to construction.

17. By the application of known principles, concrete of a definite strength at a given time can be made. If, for any reason, the design strength is not

attained, it is no fault of the material, but rather the fault of poor methods, such as inefficient design of the concrete or careless supervision during making, placing and curing. Until recently the accepted practice has been to use conservative unit stresses in design. The compressive unit stresses in the extreme fibres of concrete rarely exceeded 600 pounds per square inch. Concrete was thought of as a material, the ultimate compressive strength of which would be about 2,600 pounds per square inch. With the advance in knowledge, and the more universal attainment of higher strength at 28 days, it has become evident that the old unit stresses used in design are uneconomical, and not truly representative of the material.

18. The trend of specifications for Concrete and Reinforced Concrete is to recommend that the unit stresses for design shall be based upon the ultimate compressive strength of concrete at the age of 28 days. This is based on the requirement that the concrete shall meet the designed strength as shown by standard tests. This allows the use of stresses entirely commensurate with the quality of the material, and permits the attainment of economy and utility. If it can be assumed that efficient engineering supervision of concrete can be obtained in bridge work, the designer will be able to use commensurate stresses that will directly influence his work. Longer spans will be made possible. The thickness of slabs may be reduced as much as 33 per cent. for the same span. Weights of slabs will be reduced in proportion, thereby cutting down the dead load. Structural sections such as piers and other supporting members may be reduced in size, and with this will come the knowledge that more uniformly satisfactory concrete is going into the work.

19. *Argument in favour of increased unit stresses.*—The strength of almost all portland cements throughout the world has been considerably increased during recent years and this is very clearly demonstrated as regards British Cements by the following table:—

British Standard Specification.

1 : 3 Cement Sand Tensile Strengths at seven days.

Year.	Pounds per square inch.
1904	120
1907	150
1910	150
1915	200
1920	200
1925	325
1931	375

20. Even among standard brands there is a slight variation in the rate of gain of strength. Generally, however, all brands approach very closely the same strength at the age of one year and later. With portland cement of Indian manufacture the results obtained at seven days are well over 600 pounds per square inch, and a still higher figure is obtained with Rapid Hardening Cement.

21. As can be seen from the above table, these tensile tests indicate that the strength of cement on the basis of the tensile stress has almost doubled in the last 20 years. Corresponding compression tests indicate an even greater increase. In practice however we are solely concerned with

the crushing strength of concrete, as generally the tensile strength is neglected and the compressive strength only is relied on. There are a few exceptions to this statement but generally it is correct. It can be seen therefore that the tests of cement specimens in compression would be more satisfactory than those in tension. The relative merits of various cements would be more accurately given if a standard aggregate could be agreed upon and specimens in the form of either cubes or cylinders made with definite proportions of cement, standard sand and standard coarse aggregate, and tested in compression.

22. There is however a rough relation between the tensile strength of 1:3 cement mortar and concrete, and it may be taken as being approximately equal to concrete consisting of 1 part cement, 2 parts sand and 4 parts stone. Also the crushing strength of all mortars and concretes is somewhere between 10 to 15 times the tensile strength. The precise ratio depends on such factors as the water-cement ratio and the age of the specimen. For example a 1:3 sand cement cube fails at 600 pounds per square inch at 28 days in tension. A 1:2:4 concrete would have a crushing strength of about 6,000 pounds per square inch if the water-cement ratio could be maintained. Where a wetter concrete than would be suitable for testing purposes has to be used, the concrete strength would probably be between 4,000 and 5,000 pounds per square inch. In view of these figures it seems reasonable that working stresses can now be increased considerably in the interests of economy. The following tables of working stresses adopted in previous years are of interest:—

	1 : 2 : 4 concrete R. I. B. A. Report, 1907.	1 : 2 : 4 concrete R. I. B. Report, 1911, and L. C. C. Regulations, 1915.
	lbs. per sq. inch.	lbs. per sq. inch.
Concrete in compression in beams subject to bending.	600	600
Concrete in columns under simple compression.	500	500
Concrete in shear in beams	60	60
Adhesion of concrete to metal	100	100
Steel in tension	15,000 to 17,000	16,000

23. In 1931, the Roads Department of the Ministry of Transport recognised the following working stresses in highway bridge design providing that:

(1) The cement complies with the current B. E. S. A. Specification for Portland Cement.

(2) Crushing tests on 6 inch cubes made with concrete taken from the mixer during the progress of the work show consistently the results listed below.

(3) The cement is weighed and not measured in volume. It is recommended that whole bags be used to the batch so that weighing on the work becomes unnecessary.

CONCRETE MIX. Cement : Fine Aggregate Coarse ,,			Working Stress. fc	Modular Ratio.	Crushing Strength of Concrete 6 inch Cubes. At 28 days with ordinary Portland Cement. At 7 days with Rapid Hardening Portland Cement.	An Additional test (if reqd.) as an indication, at 7 days with ordinary P. C. at 3 days with R. H. P. C. should give results as below.
lbs.	C.ft.	C.ft.	lbs./sq. in.	n	lbs./sq. in.	lbs./sq. in.
A	2	4	5A+300		15A+900	10A+600
90	2	4	750	15	2,25	1,500
120	2	4	900	15	2,700	1,800
150	2	4	1,050	12	3,150	2,100
180	2	4	1,200	10	3,600	2,400

24. In the new "Code of Practice for the use of Reinforced Concrete in Buildings", issued by the Reinforced Structures Committee of the Building Research Board 1934 the corresponding stresses for 1:2:4 mix concrete are:—

—	Ordinary Grade.	High Grade.	Special Grade.
	lbs. per sq. inch.	lbs. per sq. inch.	lbs. per sq. inch.
Concrete in compression in Bending.	750	950	1,187
Concrete in direct compression.	600	760	950
Concrete in Shear	75	95	150
Bond	100	120	150
Steel in Tension	18,000 or 20,000 Where Yield Point Stress is not less than 44,000 lbs.	18,000 or 20,000 Where Yield Point Stress is not less than 44,000 lbs.	18,000 or 20,000 Where Yield Point Stress is not less than 44,000 lbs.

25. The following notes have been extracted from the "Handbook on the Code of Practice for Reinforced Concrete".

STRENGTH REQUIREMENTS AND PERMISSIBLE STRESSES.

Concrete.

(a) *Grades of Concrete.*—Three grades of concrete designated Ordinary Grade, High Grade and Special Grade shall be recognised. The requirements for each grade shall be as follows:—

(b) *Ordinary Grade Concrete.*—(i) Strength and consistence tests shall be made when required by the Designer and shall then be carried out as specified in Appendices (VII), (VIII) and (VI) respectively.

(ii) The minimum cube strengths, the permissible stresses and the appropriate value of the modular ratios for Ordinary Grades Concrete shall be as given in Table 1.

(c) *High-grade Concrete.*—(i) Preliminary tests shall be made prior to the commencement of the work and in accordance with Appendix (VII) unless satisfactory evidence of strength is produced from reliable sources.

(ii) The work shall be carried out under special supervision throughout and shall be in charge of a Foreman and a responsible Supervisor or Clerk of Works, both competent and qualified for the execution of reinforced concrete work.

(iii) Works tests for strength and consistence shall be carried out as specified in Appendices (VIII) and (VI) respectively. At least two strength cubes shall be tested weekly and whenever any of the materials or the mix is changed. At least one consistence test shall be made daily. The first of such strength and consistence tests shall be made immediately concreting is commenced.

(iv) The minimum crushing strengths, the permissible stresses and the appropriate values of the modular ratios for High Grade Concrete shall be as given in Table 2.

(d) *Special Grade Concrete.*—(i) The requirements for High Grade concrete given above in paragraphs (i) and (ii) shall be complied with.

(ii) The structure or portion of a structure in which Special Grade concrete is to be used shall be calculated and designed as a continuous monolithic frame-work, bending in all members being taken into account.

(iii) Special provision shall be made to ensure a uniform supply of cement throughout the work.

(iv) The water content, including the moisture in the aggregates, shall be controlled in such a manner that the ratio of the water to the cement will not at any time exceed the ratio used in the preliminary tests by more than 10 per cent.

(v) The grading of the aggregates shall be carefully controlled throughout the work in order to ensure that at all times it shall conform closely to that used for the preliminary tests.

TABLE 1.

Ordinary Grade Concrete.

Mix. Ref.	Nominal Mix.	Proportions. Cub. ft. of Aggregate per 112 lb. bag of cement.		Minimum Cube Strength Requirements at 28 days. Optional Tests; See Cl. 301 (*b*) (*i*) Lb. per sq. in.		Modular Ratio.	Permissible Concrete Stresses. Lb. per sq. inch.			
		Fine.	Coarse.	Preliminary Tests.	Works Tests.		Bending.	Direct.	Shear.	Bond.
				$4{\cdot}5\,x$	$3\,x$	$\dfrac{40{,}000}{3\,x}$	x	$0{\cdot}8\,x$	$0{\cdot}1\,x$	$0{\cdot}1\,x + 25$
I	1 : 1·2 . . .	1¼	2½	4,388	2,925	14	975	780	98	123
II	1 : 1·2 : 2·4 . .	1½	3	4,163	2,775	14	925	740	93	118
III	1 : 1·5 : 3 . .	1⅞	3¾	3,825	2,550	16	850	680	85	110
IV	1 : 2 : 4 . .	2½	5	3,375	2,250	18	750	600	75	100

Where other proportions of fine to coarse aggregate are used the requirements shall be based on the ratio of the sum of the volumes of the fine and coarse aggregates, *each measured separately* to the quantity of cement, and shall be obtained by proportion *from the two nearest* defined mixes.

The tabulated values of the modular ratios are given to the nearest whole number; *nevertheless*, more exact values, calculated from the formula 40,000/3 x, may be used.

TABLE 2.

High Grade Concrete.

Mix. Ref.	Nominal Mix.	Proportions. Cub. ft. of Aggregate per 112 lb. bag of cement.		Minimum Cube Strength Requirements at 28 days. Lb. per sq. in.		Modular Ratio.	Permissible Concrete Stresses. Lb. per sq. in.			
		Fine.	Coarse.	Preliminary Tests.	Works Tests.		Bending.	Direct.	Shear.	Bond.
				$4 \cdot 5\,x$	$3\,x$	$\frac{40,000}{3\,x}$	x	$0 \cdot 8\,x$	$0 \cdot 1\,x$	$0 \cdot 1\,x + 25$
I	1 : 1 : 2 . . .	$1\frac{1}{4}$	$2\frac{1}{2}$	5,625	3,750	11	1,250	1,000	125	150
II	1 : 1·2 : 2·4 . .	$1\frac{1}{2}$	3	5,400	3,600	11	1,200	960	120	145
III	1 : 1·5 : 3 . .	$1\frac{7}{8}$	$3\frac{3}{4}$	4,950	3,300	12	1,100	880	110	135
IV	1 : 2 : 4 . . .	$2\frac{1}{2}$	5	4,275	2,850	14	950	760	95	120

Where other proportions of fine to coarse aggregate are used the requirements shall be based on the ratio of the sum of the volumes of the fine and coarse aggregates, each measured separately, to the quantity of cement, and shall be obtained by proportion from the two nearest defined mixes.

The tabulated values of the modular ratios are given to the nearest whole number; nevertheless, more exact values, calculated from the formula $40,000/3x$, may be used.

TABLE 3.

Special Grade Concrete (Limiting values).

Mix. Ref.	Nominal Mix.	Proportions. Cub. Ft. of Aggregate per 112 lb. bag of cement.		Minimum Cube Strength Requirements at 28 days. Lb. per sq. in.		Modular Ratio.	Permissible Concrete Stresses. Lb. per sq. in.			
		Fine.	Coarse.	Preliminary Tests.	Works Tests.		Bending.	Direct.	Shear.	Bond.
				$5x$	$3x$	$\frac{40,000}{3x}$	x	$0 \cdot 8x$	$0 \cdot 1x$ but not greater than 150.	$0 \cdot 1x + 25$ but not greater than 150.
I	1 : 1 : 2 . . .	$1\frac{1}{4}$	$2\frac{1}{2}$	Strength requirements, modular ratios and permissible stresses to be calculated from above factors and to be used on preliminary test results. The values for the permissible stresses shall not exceed those for similar mixes of high grade concrete (Table 2) by *more than 25 per cent.* Shear and bond stresses shall also not exceed 150 lb. per sq. in. Modular ratios may be taken to the nearest whole number.						
II	1 : 1·2 : 2·4 . .	$1\frac{1}{2}$	3							
III	1 : 1·5 : 3 . .	$1\frac{7}{8}$	$3\frac{3}{4}$							
IV	1 : 2 : 4 . ; .	$2\frac{1}{2}$	5							

Where other proportions of fine to coarse aggregate are used the requirements shall be based on the ratio of the sum of the volumes of the fine and coarse aggregates, each measured separately, to the quantity of cement, and shall be obtained by proportion from the two nearest defined mixes.

(vi) Works tests for strength and consistence shall be carried out as specified in Appendices (VIII) and (VI) respectively. At least two series of two strength cubes shall be tested weekly and in addition whenever any of the materials or the mix is changed. At least one consistence test shall be made daily. The first of such strength and consistence tests shall be made immediately concreting has commenced.

(vii) The permissible stresses shall be based on the results of the preliminary cube tests and shall not exceed the values permitted for similar mixes of High Grade Concrete by more than 25 per cent. Shear and bond stresses shall also not exceed 150 pounds per square inch.

The permissible stresses, the minimum crushing strengths required from the works tests, and the appropriate modular ratios shall be obtained from the relations given in the headings of Table 3.

(viii) Where it can be shown that the conditions under which the work is to be carried out are favourable with regard to temperature and humidity, and such that there is no risk of temperatures less than 50° F. during the placing of the concrete and that the concrete will be maintained in a damp condition for at least 14 days, the preliminary test requirements given in Table 3 may be reduced by 20 per cent. (*i.e.*, may be taken as equal to 4x.)

(e) *General.*—For all grades of concrete where the strengths specified in Tables 1, 2 or 3 are reached before the age of 28 days these earlier tests may be accepted.

Where the works cube tests at the age of 28 days show strengths which fall below the appropriate values in the Tables the concrete shall not be condemned if subsequent tests at the age of 56 days show strengths not less than the figures specified for the age of 28 days *plus* 10 per cent.

Where works cube tests show strengths consistently above those specified the Designer may authorise a reduction in the number of tests required.

In no case should the consistency of the concrete be such as to produce a slump, when tested in accordance with Appendix VI, of more than 6 inches, and wherever possible a smaller slump should be maintained.

(f) *Method of Measuring Materials.*—The quantity of cement shall be determined by weight.

The quantities of fine and coarse aggregate shall be separately determined either by volume or equivalent weight.

(g) *Proportions.*—Concrete in the proportions given in Tables 1, 2, and 3 or in intermediate proportions shall be recognised for all grades of concrete.

The volume of coarse aggregate shall be twice that of the fine aggregate except that when specially authorised by the Designer it may be varied within the limits of one and a half and two and a half times the volume of fine aggregate.

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26. The three grades of concrete are distinguished principally by the degree of control of concrete quality that is demanded. The use of higher stresses is made to depend upon the care taken in carrying out the work.

27. For Ordinary-Grade concrete no tests need be made except when required by the designer. As a rule such tests are only likely to be necessary with untried aggregates or when there may be reason to doubt the

suitability of any of the materials. Provided sound aggregates and cement complying with Section 2 are used no difficulty should be experienced in producing concrete of a satisfactory quality.

28. For High-Grade concretes preliminary tests or other reliable evidence of strength are demanded. Special supervision is required and the *control of the concrete is ensured by frequent testing.* No good quality aggregate used with cement complying with B. S. S. No. 12 should fail to give the strengths specified provided reasonable care is taken to ensure correct proportioning of the materials including the water.

29. For Special-Grade concrete still more stringent control and more frequent testing are demanded. Preliminary test results are made the basis of the permissible stresses. The large margin existing between the preliminary and works test requirements should be adequate to allow for any factors still uncontrolled. Table 6 gives the requirements for concrete of each grade.

30. *Preliminary Tests.*—The requirements for the preliminary tests and the method of making the tests set out in Appendix VII should be carefully noted. The specified water content of 30 per cent. of the cement by weight, plus 5 per cent. of the aggregate by weight ensures that the strength of the concrete in the preliminary tests shall not be unduly high as a result of the use of a much smaller quantity of water than could be used in the concrete as placed in the structure. It should be noted nevertheless that the designer may authorise the use of less water for the preliminary tests provided that this reduced quantity is also used in the work.

31. *Works strength Tests.*—The method of carrying out works strength tests given in Appendix VIII follows the lines laid down for preliminary tests. A difficulty that does not arise in the case of preliminary tests is that of sampling which has to be done, wherever practicable, from the concrete after it has been placed in the work. It is fundamentally important that proper care be taken to ensure that the sample is as representative as possible. It is undesirable, for example, to take concrete from the top surface as placed. Such a sample may contain an excess of water and be deficient in aggregate.

32. It is known that the strength of concrete compacted in the manner specified is dependent on the amount of the compacting, but the increase in strength with increase in compacting becomes very small after a certain point. The amount of compacting laid down is sufficient to ensure that this point is reached with concretes of practical consistence, and therefore that variations in strength arising from differences in compacting are reduced to a minimum.

33. In interpreting the results of works tests it is important that due regard be given to the temperatures experienced. It should be realised also that the strength of the 6-in. cube will be representative only of comparatively small masses of concrete. In general, the heat generated by the cement in setting and hardening will result in increased temperatures, and therefore enhanced rates of hardening for larger masses of concrete.

34. The requirement that two cubes shall be tested weekly for strength in the case of High-Grade concrete and two series of two cubes for Special-Grade concrete indicates that the two cubes may in each case be taken at

the same time, and that the average crushing strength of these two cubes may be employed as a criterion of the compressive strength of the concrete. It will be noted that when the 28-day tests fail to give the strength specified, further tests at the age of 56 days may be made. To enable these subsequent tests to be carried out additional cubes would have to be made at the same time as the 28-day cubes.

TABLE 6.

Requirements.	Ordinary Grade.	High Grade.	Special Grade.
Preliminary Tests. (a) Strength. (b) Consistence.	Optional . .	To be made unless satisfactory evidence is produced.	As High Grade.
Works Tests : (a) Strength . (b) Consistence.	Optional . .	(a) Two cubes weekly and when materials are changed. (b) Daily.	(a) Two series of two cubes weekly and when materials are changed. (b) Daily.
Supervision . .	No special provision	Foreman and responsible supervisor qualified for reinforced concrete work.	As High Grade.
Water content and consistence.	Slump should not be more than 6″ and should be less where possible.	As Ordinary Grade .	As Ordinary Grade and water-cement-ratio not to exceed preliminary test figure by more than 10 per cent.
Supply of cement .	No special requirement.	No special requirement.	Special provision for uniform supply.
Grading of aggregates.	No special requirement.	No special requirement.	Carefully controlled to ensure close conformity to preliminary tests.
Calculation of structure.	No special requirement.	No special requirement.	As monolithic framework.

35. *Water Content and Consistence.*—The tests for consistence (slump test) in Appendix VI are made with the object of controlling the uniformity of the concrete under any given set of conditions. It cannot be rigidly laid down that certain classes of work should be done with concrete of one slump and other classes with concrete of another slump, since it is known that the workability, or amount of work required to place the concrete, is not always the same for mixes of the same slump. The exact slump to which it is desirable to work depends on the grading and degree of sharpness of the aggregates, the cement content, and the nature of the cement, whether finely or coarsely ground. In this connection reference should be made to the discussion of Clause 202 (*d*), "Grading". The figure of 6 inches is a slump which should be regarded as a maximum. Usually the most satisfactory work is obtained with concrete having a slump ranging from 2 inches to 4 inches, although for thin sections it is often necessary to use wetter concrete, while in large sections it may be possible to work to a smaller slump.

The water content required to enable successful placing varies with the method of consolidation adopted. Thus with the assistance of vibrators it is often possible to reduce the water content to a marked extent.

36. For Special-Grade concrete the requirement that the ratio of water to cement shall not exceed that used in the preliminary tests by more than 10 per cent. is not likely to cause any great difficulties in application, since an increase of 10 per cent. will for all ordinary mixes, cause an appreciable change in slump. A difficulty that arises in this connection is the variation of the moisture contained in the aggregates, and the resultant change in volume (or bulking) that occurs. Errors arising from this cause are greatest when aggregates are measured by volume. They can be minimised to a great extent by maintaining the aggregates, particularly the fine aggregate, in a wet condition.

37. *Control of Aggregate Grading for Special-Grade Concrete.*—The requirement that grading of the aggregates shall conform closely to that for preliminary tests needs careful consideration. It would have been helpful had "conform closely" been more precisely defined. The necessary degree of conformity must depend on how far variations in grading are likely to affect strength. In general, provided the ratio of water to cement is not varied and the concrete is efficiently compacted, large variations in grading may be made without appreciably affecting the strength. It is found, however, that certain variations in grading, such as an increase of fine material, necessitate increased water to give the same degree of workability. Consequently, since it is important to maintain the workability of the concrete and since more water means lower strength concrete, such variation is undesirable.

38. The importance of close control of grading depends on the cement content, with a 1:1:2 mix large variations in grading produce only small differences in strength, with leaner mixes the grading becomes more important. The variations in grading most likely to cause serious differences arise from changes in the quantities of the fine particles (those passing through a No. 52 sieve). To ensure sufficient uniformity of the concrete the quantity of fine material in a 1:2:4 mix should not be permitted to vary by more than 5 per cent. of the weight of the fine aggregate.

Variations of 10 per cent. in any other grade between any two adjacent standard sieves are not likely to cause serious differences in workability except in the intermediate sizes (the larger sizes of the fine aggregate and the smaller sizes of the large aggregate) which should not be unduly increased. The limits given may be doubled in the case of a 1:1:2 mix, and intermediate mixes may be treated proportionately.

39. *Uniform Supply of Cement for Special-Grade Concrete.*—Where the amount of Special-Grade concrete is small and only a very limited quantity of cement is needed, uniformity may be ensured by setting aside or ordering the quantity of cement required from one works and by tests on samples taken after delivery. Where the amount of cement is large arrangements should preferably be made for supply from an independently tested sealed bin at the cement works.

40. *Rapid-Hardening Cements.*—It will be noted that special stresses are not permitted for rapid-hardening cements and that 28 days is taken as the basic age for all strength tests. It is stated, nevertheless, that where the specified strengths are reached before 28 days these earlier tests may be accepted. Rapid Hardening cements are therefore intended to be regarded as of value in so far as they facilitate speedier construction and not as ultimately producing a sounder or stronger structure than normal cements.

41. *To obtain the Appropriate Strength Requirements, Permissible Stresses, etc., for Intermediate Mixes.*—If the two nearest defined mixes are such that the sums of the volumes of the fine and coarse aggregates per 112 pound of cement are S_1 and S_2 respectively, and the corresponding permissible stresses in bending are X_1 and X_2 then for an intermediate mix S' the corresponding stress in bending X' will be—

$$X'_1 = X^J + \frac{(X_1 - X_2)(S_2 - S_{,2})}{(S_2 - S_1)}$$

The appropriate strength requirements, modular ratios, and other permissible stresses can now be obtained from the factors given in the headings of the tables.

Example.—For Ordinary-Grade concrete mixed in the proportions of 112 lb. of cement to 2 cubic feet of fine aggregate and 3 cubic feet of coarse aggregate, the sum of the volumes of the aggregates is 5 cubic feet. This lies between No. II and No. III mix. for which the sums of the volumes of aggregates are $4\frac{1}{2}$ and $5\frac{5}{8}$ cubic feet respectively, the corresponding stresses in bending being 925 and 850 pounds per square inch. The stress in bending for the 112 pound 2:3 mix is then—

$$X' = 850 + \frac{(925 - 850)(5\frac{5}{8} - 5)}{(5\frac{5}{8} - 4\frac{1}{2})}$$

$= 892$ pounds per square inch.

TABLE 4.

	Permissible stress Lb. per sq. in.	
	(1)	(2)
——	Mild Steel complying with B. S. S. No. 15.	Mild Steel complying with B.S.S. No 15 and with a Yield Point Stress of not less than 44,000 lb. per sq. in. *See* Appendix (V).
Bending.		
Tension in longitudinal steel in beams, slabs or columns subject to bending.	18,000	20,000
Compression in longitudinal steel in beams, slabs or columns subject to bending where the compressive resistance of the concrete is taken into account.	The compression stress in the surrounding concrete multiplied by the modular ratio.	
Compression in longitudinal steel in beams where the compressive resistance of the concrete is not taken into account.	18,000	20,000
Direct Compression.		
Compression in longitudinal steel in axially loaded columns.	13,500	15,000
Tension in Spiral reinforcement . . .	13,500	15,000
Shear.		
Tension in web reinforcement . . .	18,000	18,000

42. *Reinforcement*—

(*a*) *General.*—The stresses in the steel reinforcement shall not exceed the values given in Table 4.

Where the stresses given in column (2) are used, only steel complying with the requirements stated in the heading shall be used throughout the job.

(*b*) *High Yield Point Steel.*—In solid slabs, other than flat slabs, subject to bending, the permissible stress complying with B. S. S. No. 165 for Hard Drawn Steel Wire or other Specification for high yield point steel approved by the competent Building Authority may be increased up to a value equal to 0·45 of the yield point stress but not exceeding 25,000 pounds per square inch providing that the area of steel in tension does not exceed 1 per cent. of the effective area of the slab.

The basic factor of safety on the yield point stress of the steel is taken as 2·2. Other considerations may, however, decide the limit to which it

is safe to stress the steel. These arise from cracking that occurs in the tension side of reinforced concrete members subjected to bending. This cracking is for all practical purposes quite independent of the quality of the steel used since it depends upon the modulus of elasticity of the steel, which does not vary appreciably. The adoption of a maximum permissible stress in the steel of 20,000 pounds per square inch provides the necessary safeguard in this connection. In the special case of solid slabs when the percentage of steel is low, the concrete in the tension zone will contribute appreciably to the tensile resistance, and in this case a higher stress is permitted subject to the required factor of safety upon the yield point stress being realised.

43. The following table of allowable unit stresses was compiled in 1928 on the basis of the recommendations of the Joint Committee U. S. A. Concrete strengths at 28 days of 2,000, 2,500 and 3,000 pounds per square inch, are used. It is frequently desired to use concrete of higher strength, up to 5,000 pounds per square inch, in which case the recommended stresses may be proportionately increased, the factor of f'c in the first column determining the stress value.

TABLE OF ALLOWABLE UNIT STRESSES.

Description.	Allowable unit stresses.			
	For any strength of concrete as fixed by tests in accordance with standard methods.	When strength of concrete at age of 28 days is assumed as the values indicated.		
	$n = \frac{30,000}{f'c}$	f'c = 2,000 lbs. n = 15.	f'c = 2,500 lbs. n = 12.	f'c = 3,000 lbs. n = 10.
Direct Compression.				
Piers and Pedestals	0·25 f'c	500	625	750
Columns whose length does not exceed 40 R, with long'l. reinforcement and lateral ties (when amount of long'l. reinforcement is not more than 2 per cent. nor less than 0·5 per cent. of total area of column; and lateral ties are not less than ¼" in diameter spaced not more than 8 in. apart).	0·20 f'c	400	500	600
Compression due to bending.				
Beams and Slabs	0·40 f'c	800	1,000	1,200
Arch rings including temperature and rib shortening.	0·40 f'c	800	1,000	1,200
Shear (diagonal tension).				
(Longitudinal bars without special anchorage).				
Beams, without web reinforcement .	0·02 f'c	40	50	60
Beams with stirrups or bent bars, or a combination of the two.	0·06 f'c	120	150	180
(Long'l. bars with special anchorage.)				
Beams without web reinforcement .	0·03 f'c	60	75	90
Beams, with stirrups or bent up bars, or a combination of the two.	0·12 f'c	240	300	360

44. I think it will be admitted that the art of making concrete has improved considerably since 1907. We also know that the strength of cement has more than doubled since 1907, yet the permissible increases in working stresses, considering Ordinary Grade concrete, are only as follows:—

Concrete in compression in bending, 25 per cent. over 1907.

Concrete in direct compression 20 per cent. over 1907.

Concrete in Shear, 25 per cent. over 1907.

Bond, 0 per cent. over 1907.

45. If we consider High Grade Concrete the permissible increase in concrete stress is:—

Concrete in compression in bending 58 per cent. over 1911.

Concrete in direct compression, 27 per cent. over 1911.

Concrete in shear, 58 per cent. over 1911.

Bond 20 per cent. over 1911.

It will be noted from the extracts from the Code of Practice that in the case of High Grade and Special Grade Concrete the work shall be carried out under special supervision and shall be in charge of a Foreman and a responsible supervisor both competent and qualified for the execution of reinforced concrete work. Such supervision can I think generally be supplied on most important works in India where reputable and specialised contractors are employed together with experienced engineers in charge.

46. Strength specifications for concrete although not yet in vogue in this country have been current practice in America and Europe for many years. This is evidence that engineers and contractors are moving beyond the theoretical consideration of the scientific control of concrete mixes into practical applications that will undoubtedly indicate economy and efficiency. I therefore see no reason why stresses up to the standard of High Grade Concrete could not now be allowed in India, but with the strict proviso that only where experienced contractors are employed.

47. I have endeavoured to put before you arguments in favour of the use of increased unit stresses in concrete design. To many of you the suggestions may appear somewhat radical, based on your experience of some of the practices in vogue in this country. I admit there are some glaring examples of bad workmanship but these are generally due to:—

(a) The custom of accepting the lowest tender.

(b) Specifications which are not sufficiently precise, and therefore the best practice in making concrete cannot be enforced.

(c) Employment of inexperienced contractors.

My own experience in India is that the younger generation of engineers, on whom devolves the duty of supervision, undoubtedly takes a very keen interest in the latest methods of concrete making. Occasionally they err, especially in going to the extreme of making the concrete too dry, but this in itself is a proof that they recognise that the old fashioned methods are now obsolete.

APPENDIX VI OF CODE OF PRACTICE.

Standard Method of Test for Consistence of Concrete.

The test is to be used in the laboratory and during the progress of the work for determining the consistence of concrete.

The test specimen shall be formed in a mould in the form of the frustum of a cone with internal dimensions as follows:—Bottom diameter, 8 feet: top diameter, 4 feet and height, 12 feet. The bottom and the top shall be open, parallel to each other, and at right angles to the axis of the cone. The mould shall be provided with suitable foot pieces and handles. The internal surface shall be smooth.

Care shall be taken to ensure that a representative sample is taken.

The internal surface of the mould shall be thoroughly clean, dry and free from set cement before commencing the test.

The mould shall be placed on a smooth, flat non-absorbent surface, and the operator shall hold the mould firmly in place, while it is being filled, by standing on the foot pieces. The mould shall be filled to about $\frac{1}{4}$ of its height with the concrete which shall then be puddled, using 25 strokes of a $\frac{5}{8}$ inch rod, 2 inches long, bullet pointed at the lower end. The filling shall be completed in successive layers similar to the first and the top struck off so that the mould is exactly filled. The mould shall then be removed by raising vertically, immediately after filling. The moulded concrete shall then be allowed to subside and the height of the specimen measured after coming to rest.

The consistence shall be recorded in terms of inches of subsidence of the specimen during the test, which shall be known as the slump.

It should be remembered that although the slump test where carefully applied, is a means of maintaining reasonably uniform consistence with any given aggregate and cement, it is not a true measure of workability and where materials are changed it may be necessary to change the slump.

In accordance with Appendices VII and VIII slump tests are required whenever preliminary or works cubes are made. In the case of works tests it is particularly important that the results of these tests should accompany the cubes when forwarded to the testing laboratory, as they are frequently of service in interpreting the cube strength results.

Appendix VII of Code of Practice.

Standard Method of making Preliminary Cube Tests of Concrete.

The method described applies to compression tests of concrete made in a laboratory where accurate control of materials and test conditions is possible.

Materials and Proportioning.—The materials and the proportions used in making the preliminary tests shall be similar in all respects to those to be employed in the work. The water content shall be as nearly as practicable equal to that to be used in the work, but shall be not less than the sum of 30 per cent. by weight of the cement and 5 per cent. by weight of the aggregate unless specially authorised by the Designer. For porous aggregates additional water shall be used to allow for the amount absorbed by the aggregates.

Materials shall be brought to room temperature (58 to 64°F.) before beginning the tests. The cement on arrival at the laboratory shall be mixed dry either by hand or in a suitable mixer in such a manner as to ensure as uniform a material as possible care being taken to avoid intrusion of foreign matter. The cement shall then be stored in air-tight containers until required. Aggregates shall be in a dry condition when used in concrete tests.

The quantities of cement, aggregate and water for each batch shall be determined by weight to an accuracy of 1 part in 1,000.

Mixing Concrete.—The concrete shall be mixed by hand or in a small batch mixer in such a manner as to avoid loss of water. The cement and fine aggregate shall first be mixed dry until the mixture is uniform in colour. The coarse aggregate shall then be added and mixed with the cement and sand. The water shall then be added and the whole mixed thoroughly for a period of not less than two minutes and until the resulting concrete is uniform in appearance.

Consistence.—The consistence of each batch of concrete shall be measured, immediately after mixing by the slump test made in accordance with the Method of Test for Consistence of Concrete given in Appendix VI. Providing that care is taken to ensure that no water is lost the material used for the slump tests may be re-mixed with the remainder of the mix before making the test specimen.

Size of test cubes.—Compression tests of concrete shall be made on 6-inch cubes. The moulds shall be of steel or cast iron with inner faces accurately machined in order that opposite sides of the specimen shall be plane and parallel. Each mould shall be provided with a base plate having a plane surface and of such dimensions as to support the mould during filling without leakage and preferably attached by springs or screws to the mould. Before placing the concrete in the mould both the base plate and the mould shall be oiled to prevent sticking of the concrete.

Compacting.—Concrete test cubes shall be moulded by placing the fresh concrete in the mould in three layers, each layer being rammed with a steel bar, 15 inches long, and having a ramming face of 1 inch square and a weight of 4 pounds. For mixes of 1½ inch slump or less, 35 strokes of the bar shall be given for each layer; for mixes of wetter consistence this number may be reduced to 25 strokes per layer.

Cubing.—All test cubes shall be placed in moist air of at least 90 per cent. relative humidity and at a temperature of 58°F. to 64° for 24 hours (*plus* or *minus* half an hour) commencing immediately after moulding is completed. After 24 hours the test cubes shall be marked, removed from the moulds, and placed in water at a temperature of 58°F. to 64°F. until required for test.

Method of testing.—All compression tests on concrete cubes shall be made between smooth plane steel plates, without end packing, the rate of loading being kept approximately at 2,000 pounds per square inch, per minute. One compression plate of the machine shall be provided with a ball seating in the form of a portion of a sphere the centre of which falls at the central point of the face of the plate.

All test cubes shall be placed in the machine in such manner that the load shall be applied to the sides of the cubes as cast.

Distribution of Specimens and Standard of Acceptance.—For each age at which tests are required, three cubes shall be made and each of these shall be taken from a different batch of concrete.

The acceptance limits are a difference of 15 per cent. of the average strength between the maximum and minimum recorded strengths of the three cubes. In cases where this is exceeded repeated tests shall be made excepting where the minimum strength test result does not fall below the strength specified.

It should be fully realised that the preliminary tests must be carried out under properly controlled conditions and unless fully competent operators are employed it may be difficult to comply with the requirement for standard of acceptance.

With some aggregates the specified minimum quantity of mixing water may be excessive and it can then be reduced by special authority from the designer.

For preliminary tests the quantities of the materials are to be determined by weight. On the work the cement has to be used in weighed quantities but the aggregates may be determined by volume. The basis of the proportions of the aggregates may therefore be one of volume on the work and of weight for the preliminary tests. Consequently in making preliminary tests it may be necessary first to determine the weights per unit volume of the aggregates. For this purpose the weight of aggregate required to fill a container of known volume must be ascertained. This should be done with the aggregate in a dry condition, the aggregate being well shaken down. In this determination errors outside the accuracy demanded for the measurement of the weight, namely one part in one thousand, will be introduced as a result of the difficulty of obtaining a standard amount of compacting of the aggregate. However, since the strength is mainly dependent on the ratio of the water to the cement, both of which can be measured accurately, the errors should not appreciably affect the strength of the concrete obtained.

Appendix VIII of Code of Practice.

Standard Method of making Works Cube Tests of Concrete.

The method described applies to compression tests of concrete sampled during the progress of the work.

Size of Test Cubes and Moulds.—The test specimens shall be 6 inch cubes. The moulds shall be of steel or cast iron, with inner faces accurately machined in order that opposite sides of the specimen shall be plane and parallel. Each mould shall be provided with a base plate having a plane surface and of such dimensions as to support the mould during filling without leakage and preferably attached by springs or screws to the mould. Before placing the concrete in the mould both the base plate and the mould shall be oiled to prevent sticking of the concrete.

Sampling of concrete.—Wherever practicable concrete for the test cubes shall be taken immediately after it has been deposited in the work. Where this is impracticable samples shall be taken as the concrete is being delivered at the point of deposit, care being taken to obtain a representative sample. All the concrete for each sample shall be taken from one place. A sufficient number of samples, each large enough to make one test cube, shall be taken at different points so that the test cubes made from them will be representative of the concrete placed in that portion of the structure selected for tests. The location from which each sample is taken shall be noted clearly for future reference.

In securing samples the concrete shall be taken from the mass by a shovel or similar implement and placed in a large pail or other receptacle, for transporting to the place of moulding. Care shall be taken to see that each test cube represents the total mixture of concrete from a given place. Different samples shall not be mixed together but each sample shall make one cube. The receptacle containing the concrete shall be taken to the place where the cube is to be moulded as quickly as possible and the concrete shall be slightly re-mixed before placing in the mould.

Consistence.—The consistence of each sample of concrete shall be measured, immediately after re-mixing, by the slump test made in accordance with the Method of Test for Consistence of Concrete given in Appendix VI.

Providing that care is taken to ensure that no water is lost the material used for the slump tests may be re-mixed with the remainder of the mix before making the test cube.

Compacting.—Concrete test cubes shall be moulded by placing the fresh concrete in the mould in three layers, each layer being rammed with a steel bar 15 inches long and having a ramming face of 1 inch square and a weight of 4 pounds. For mixes of 1½ inches slump or less, 35 strokes of the bar shall be given for each layer; for mixes of wetter consistence the number may be reduced to 25 strokes per layer.

Curing.—The test cubes shall be stored at the site of construction, at a place free from vibration, under damp sacks for 24 hours (*plus* or *minus* half an hour) after which time they shall be removed from their moulds, *marked and buried in damp sand until the time for sending to the testing* laboratory. They shall then be packed in damp sand or other suitable damp material and sent to the testing laboratory, where they shall be similarly stored until the date of test. Test cubes shall be kept on the site for as long as practicable but at least three-fourths of the period before test except for tests at ages less than seven days.

The temperature of the place of storage on the site shall not be allowed to fall below 40°F., nor shall the cubes themselves be artificially heated.

Record of temperatures.—A record of the maximum and minimum day and night temperatures at the place of storage of the cubes shall be kept during the period the cubes remain on the site.

Method of testing.—All compression tests on concrete cubes shall be made between smooth plane steel plates without end packing, the rate of loading being kept approximately at 2,000 pounds per square inch, per minute. One compression plate of the machine shall be provided with a ball seating in the form of a portion of a sphere, the centre of which falls at the central point of the face of the plate.

All cubes shall be placed in the machine in such a manner that the load shall be applied to the sides of the cubes as cast.

In carrying out works tests it should be realised that a careful compliance with the requirements is of great importance in view of the higher stresses permitted under the Code. Care is particularly necessary in sampling the concrete. The importance of obtaining a representative sample and ensuring that this is properly placed in the mould cannot be over-estimated.

The works test is one for quality of the concrete as deposited and does not necessarily represent the strength of the concrete in the member. The strength of the member will depend on its size, the amount of heat generated by the cement, and the temperature history of the member which may not correspond with the temperature of storage of the cubes.

In estimating the strength of the member, due allowance must be made for any difference in actual workmanship. Also, in interpreting test results, attention must be given to the ramming conditions in the member. Thus in large sections the concrete may be practically self-consolidating, but in thin and confined sections it is often very difficult to obtain the same degree of compacting as that specified for the cubes.

Mr. W. J. Turnbull: Mr. Chairman and Gentlemen, Before taking up the discussion on this paper I would like you to examine the print* on compression tests which has just been handed to you.

You will note that at 28 days, the cubes made with brick aggregate and of the customary 1:2:4 mix have had an ultimate strength of over 4,000 pounds per square inch, and both the gravel and stone aggregates produced concrete well over 5,000 pounds per square inch.

Compression Strengths equal to those shown on this print would be produced by any of the portland cements manufactured in India, and in the light of such results, I think serious consideration should be given in India to permitting the stresses advocated in the Code of Practice quoted in my paper especially in major bridges where efficient supervision is usually provided. At this stage it is advisable however to issue a note of warning in order to prevent going to extremes in this matter.

In bridge members subject mainly to compression such as columns and arch members, these higher comprehensive stresses can I think be adopted without qualification and with economical advantage. For girder bridge construction, however, where the principal members are subject primarily to bending, the very important question arises as to the increase in shear and bond stresses to be permitted.

Although shearing stresses are usually regarded as being of somewhat lesser importance than the direct tensile and compressive stresses, it is generally the experience that visible defects in members of a structure are usually due to excessive shear.

For this reason the question of increasing the shear stress in concrete in direct proportion to the increase in compressive strength, should be approached with caution.

Discussion on Papers in Group 6 (Papers Nos. 26, 27 and 28).

Mr. W. A. Radice: Mr. Chairman and Gentlemen, I would like to say a few words with regard to Mr. Bannerjee's paper. I desire first to thank the author for the great trouble he has taken in assembling in one compact statement such a wealth of information, and to congratulate him for the production of a very valuable work of reference. I feel sure that anybody who may have to consider the many problems involved in the preparation of a Standard Specification, will find Mr. Bannerjee's paper invaluable.

I should now like to join issue with the author over some of his conclusions regarding impact allowances and his proposal to combine these with the standard live loading proposed by him.

I feel rather qualified to offer to the meeting a few remarks on this subject for the following reasons. Some years ago the Railway Board decided to investigate practically, by actual test, the allowances to be made in Railway Bridges for impact effects and a considerable grant of money was sanctioned for experimental work. A good deal of most valuable work was done until the postwar stringency led to its abandonment.

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* Printed at the end of the Paper No. 28 on propage.

The Railway Board entrusted the Committee of Railway Bridge Engineers with the decision both as to the nature and the conduct of the experiments and that year, decided to invite members of the Indian bridge making firms to attend the meeting. I accepted that invitation and I was present at the deliberations of the Committee and followed the actual experimental work very closely.

We talk of impact formulae as arbitrary. This is not quite correct. In the present state of our knowledge they are based on the combined results of several effects, some of which are computable, some are not. These can be divided into two classes:—

The first consists of vibrational effects such as those due to inequalities of the road surface, unbalanced rotating masses, etc., which cannot be computed mathematically.

The second class, and the most important in road bridges, is the effect due to the more or less sudden application of the live load. I propose to show that these are computable.

This effect is common to all bridges even to a bridge made of ice by the application of the weight of a block of ice sliding smoothly over it.

The whole reason of an impact formula is to provide for the increased stresses caused in each member of a bridge structure by the above two classes of effects, over and above the stresses induced in such members by the static application of the live load.

There is one common measure of this increase of stress, whether the member in question is made of concrete, steel, wood or any other material. This common measure is the increase of momentary deflection caused in the member by the more or less sudden application of the live load and it will be a maximum for each member when the live load has advanced sufficiently across the span to cause the maximum stress in that member.

I could best illustrate this in rather a novel way. Consider an elastic column resting on an unyielding base on the top of which a weight can be applied with varying degrees of suddenness by means of a vertical rope passing over a pulley. If the weight be placed on the column and left there, the elastic column will compress and become shorter by a definite amount depending on the elasticity of the material of which the column is made. If we lower the weight so as to be just in contact with the column and cut the rope, so as to apply the load instantaneously, the shortening of the column will again be a definite amount, but exactly double the previous amount. If instead of cutting the rope we left the rope out at different rates of speed we shall get deflections greater than the first, static, deflection, from 0 per cent. to 100 per cent. more than the static deflection, according to the rate at which the load is applied. If we fix a maximum rate of load application we can calculate exactly what the increase of deflection of the column will be and consequently we can ascertain exactly what the increase of stress in the column will be. There is no arbitrariness in this.

Any member of a bridge, subject to a moving load will behave exactly like the column we have just considered whether it be a vertical, horizontal or inclined member or an arch rib. It will deflect under a static load and it will momentarily deflect more when this load is applied at speed and the increased deflection measures the increase of stress we have to cater for by an impact formula. The factors that come into play in

calculating the static effect are merely the magnitude and nature of the live load and the moment of resistance of the bridge member in question. When calculating the increased effect due to the rate of application of the load, beside the above factors the following come into play:—The distance the live load has to travel before the member in question is stressed to the maximum, the time taken by the live load to cover this distance and the inertia of the member.

We can specify and fix the magnitude and nature of the live load, so that the stress in each member due to the static live load can be fixed. We can calculate the distance the live load has to travel before the member in question is stressed to the maximum and we can fix a maximum velocity for the advance of the live load across the bridge. The inertia of the member is also a known quantity, so that the impact effect due to the application of the live load within a more or less short space of time can be computed exactly, but must vary for each member of a span.

It is for these reasons that I wish to resist the suggestion that a fixed impact factor of 25 per cent of the static load be adopted, as it is obvious that an arch rib or main girder must be much less affected by a moving load than a floor slab, stringer or cross girder.

As regards the first class of vibrational effects, road bridges occupy a much more favourable position than say, railway bridges. In the latter, the inclination of the connecting rods and the unbalanced rotating masses in cranks shafts produce intense rythmical vibration. In the case of road bridges, the rotating masses are nearly perfectly balanced and even the effects of surface inequalities, such as pot-holes, are of secondary importance since all heavy vehicles moving at speed have rubber tyres. In addition the ratio of unsprung weight to sprung weight is low.

In the case of steam rollers, the width of the wheels prevents them dropping into pot-holes.

In connection with this aspect of the case, I should like to communicate to the meeting a thing which I think will be of interest. While developing an alternative design for the Howrah Bridge, the Braithwaite, Burn and Jessop Construction Company Limited have evolved a design for an all steel bridge floor which weighs only 60 to 70 pounds per square foot, inclusive of road surface. As the wheels of road vehicles come into contact only with steel, so arranged as to be non-slippery, the road surface should last, without maintenance, as long as the bridge itself and preserve its smoothness of surface throughout its life. Should such a floor be generally adopted for road bridges—and this type is not more expensive than other types of bridge floors—I feel that nearly all vibrational effects can be eliminated.

This result would not only cheapen bridges but would reduce the impact effects to those of the second class only, which, as explained, are capable of exact computation.

Mr. D. Nilsson: I should like to compliment Mr. Banerjee and Mr. Radice on their very excellent papers. They have gone into the matter most exhaustively and Mr. Banerjee's paper in particular is a very useful document. They are so much in detail that I should not like to say anything further on their subject. But about Mr. Radice's paper I should like to point out one thing. On page 342 with regard to bridges of over 500 feet length he has omitted to mention reinforced arches. There are now quite

a number of reinforced concrete bridges well over 500 feet span and I think they might have been put down too.

Mr. Radice has advocated specifications for highway bridges. I feel rather doubtful about making specifications for all the details because I fancy that might just as well be left to bridge designers. Designs are continually improving and new ideas being brought forward so that a fixed detailed specification might cramp the designers style. However, I should like to add my plea for standard loading. I myself have had to sit days and nights drawing out all sorts of designs and a large portion of my office staff also spend all its time on designs. Half of this could have been cut out if we had standard loading. All that costs money. Further in the office of every engineer or firm tackling bridge problems are a number of people spending money in the same way. If, therefore, you could fix standard loadings much of their work and overhead expenses could be cut down and there will be general saving to the purchaser in the end.

I am chiefly interested in Mr. Turnbull's paper (No. 28), regarding Concrete Bridge Designs. I think it is necessary to adopt higher standards of loading. I use a very large quantity of cement. I do not like to hurt my friend's of the Cement Marketing Co.'s feelings but I use quite a lot of English Cement. But, I am able to say that Indian Cement is certainly not inferior to English cement and generally it is better.

Mr. Turnbull gave you a graph in order to show the various results of laboratory tests conducted on the compressive strength of concrete. I should just like to add a few figures relating to the result of works tests conducted by my own firm. Since I think 1925 test cubes have been regularly made on all our works. Here are some of the results:—

(a) *At Banas Bridge* near Ajmer average compressive strength 4,430 pounds per square inch, maximum 5,350, minimum 3,450 but this cube was only 14 days old.

(b) *At Boya Bridge* in the N.-W. F. P. average 5,424 pounds per square inch. maximum 7,141, minimum 4,326.

(c) *At Banas Bridge*, average 4,670 pounds per square inch, maximum, 5,900, minimum 4,150.

(d) *At Lahore*, average 5,568 pounds per square inch, maximum 6,881, minimum 4,900.

(e) *At Ahmadabad*, average 5,940 pounds per square inch, maximum 8,626, minimum 3,100 (but this cube was damaged before testing).

(f) *At Ajmer*, average 5,775 pounds per square inch, maximum 6,800, minimum 4,400.

These were all for 1:2:4 concrete and they are not special tests that I alone have carried out. All sorts of people, engineers, foremen and mistries make test cubes and send them for crushing, so there is nothing special about them. They have become just a routine affair and the results are just average works tests figures. There are thousands of other similar figures for those who care to inspect them. Therefore I would ask you to compare these figures with the figures on page 367 of Mr. Turnbull's paper, Table No. 2—for 1:2:4 concrete, the works test required is only 2,850 pounds per square inch.

I do not see why we should lag behind the British Standards. I have been through the Code of Practice quoted by Mr. Turnbull and I think it is a very excellent thing. I do not see why that Code should not be adopted *in toto*.

Diwan Bahadur N. N. Ayyangar: Mr. President and gentlemen, this question of adoption of standards for bridge loading is a very important one. In this connection I am afraid there is a good deal of waste of energy of engineers because of the multifarious standard adopted at present in various provinces. For these we sometimes adopt steam rollers of various loads or combinations of loads. All these things lead to a mass of confusion. We have already in the British standard units very carefully prepared standards which can be adopted in this country very easily with much benefit to every body. I do not see why we should not straightaway adopt the same in this country throughout. For purposes of facility of calculation, however, we can convert them to the basis of uniformly distributed loads. That is merely as a help to us in calculations. After much discussion in the Bombay Presidency 12 units of British standard loading on each lane of 10 feet bridge has been adopted and for the more important roads with 50 per cent. impact. In the cast of industrial areas, as you see on page 271 of Mr. Banerjee's paper, 15 standard units are adopted. For the rest of the roads 8 units have been adopted. I do not see why it should not be done universally. In this connection there has been some discussion whether allowance should be made at all for impact in the case of road bridges, because the speed of vehicles on road bridges is nothing as compared with speed of railways, specially in the case of railway bridges, severe stresses of vibration, compression and tension come into play. This allowance of impact should not I think be eliminated altogether for road bridges. The percentage of allowance, if at all, may be left to the merits of each case. In the North West Frontier Province,—I think this is suggested in the other paper it is a simple business like method. I think we ought to adopt units of that kind in India.

As regards the question of concrete, I have got a few words to say. In the case of cement it is an extremely variable thing. It depends upon so many factors—the mixing, the water ratio and so many other things—When you carry out works in an out-of-the-way place you will have to depend on ordinary mistries and coolies and the result may be disastrous, if you are too meticulous and calculating. It is not necessary to make over-refined calculations. You should be liberal in making allowances and as regards factors of safety. Even in places like Bombay where you have got the very best technical advice and supervision, the results are not uniform. In one case, a whole bridge of reinforced concrete was built, but the iron inside was so much corroded that the whole thing had to be scrapped and a new steel structure put up at a very great cost. In places like Bombay and Madras, where the atmosphere is very humid and the temperature high it often occurs that reinforcement inside after 10 or 15 years is entirely corroded. In one case I know in building the whole of the cement bottom had pealed off, because the reinforcement inside had rushed and burst the concrete exposing the whole of the reinforcement. The top was supporting on itself! Can you call it reinforced concrete in that condition? I would not live in a house like that even for a few minutes. That is the danger to which reinforced concrete is generally subject. If any difficulty comes in reinforced concrete,

it is not easy to repair as we do in other cases. So we ought to be extremely cautious and conservative.

Mr. K. G. Mitchell: Mr. Chairman and Gentlemen, I have not very much to say except to thank the authors of these very valuable papers for the amount of work they have put into them and to suggest that we must now ensure that this very valuable work is not lost, and that something practical should result from it.

Mr. Banerjee I think referred to the Committee of Chief Engineers which met in 1931 and discussed standard bridge loading. But, we never got anything very definite out of that. We did get agreement more or less on the adoption of the British Standard conventional loading, but we could not get full agreement on the number of units to be adopted. When we came to the question of impact, particularly, when allowance had to be made for different types of bridges, we could get to no agreement at all.

Roads are a Transferred Subject and nobody at the Centre can say "You shall adopt a certain standard loading and a certain impact formula". At the same time, most Provinces and their Engineers would I believe be only too glad to have all India standard and we have been assured by the manufacturers of steel and reinforced concrete bridges that if such standards were adopted, there would be general economy and a great deal of time and labour would be saved. This is one of the things which this Congress could do. The Government of India cannot say "You shall adopt a certain standard loading", but this Congress can adopt a standard loading and impact formula and Engineers could then safely adopt them as those recommended by the Indian Road Congress. With that weight behind them, I think they would be generally adopted. A few conservatives might hang out for a year or two, but gradually I think every body would fall into line. Therefore what I want to suggest is that we should this morning decide on some course of action which will result in this question being followed up at once. And one suggestion which has been made is that since manufacturers and the builders often see more of the game than the individual designer in his own office, they should get together first and make proposals to be considered later by the Council of the Congress or by another Committee appointed by the Council to make definite recommendations. Personally I think that is a very good way of dealing with it. If other speakers have any more ideas we would be glad to hear them Otherwise may we decide that the matter be taken up at the Council meeting this afternoon and resolve that it should be tackled in that way? That is to say, we would ask representatives of the Steel and representatives of the Reinforced Concrete Interests to get together and make proposals regarding standard loadings and impact formula. I hope before very long, we shall be able to arrive at something which could be put up as the recommendations for standard loading and so forth, of the Indian Road Congress We must not go too fast regarding specifications. It will be something if we get a standard loading; it will be something even if we get people to agree on the conventional loading; even if they do not agree on the same number of units.

Chairman: I wish to speak on the question of standard loadings. I had one or two bridges to construct and it was a great difficulty for me to decide about the standard loading to be assumed for these bridges. If

you will kindly agree to Mr. Mitchell's proposals, we will get to something on which all the Provinces and the States can work together. I therefore support his proposal.

Mr. Syed Arifuddin: I feel that the proposal is so reasonable that nobody will oppose it. Unless anybody has alternative proposals to make, I propose that Mr. Mitchell's proposal be adopted straightaway.

Mr. M. G. Banerjee: Mr. Chairman and Gentlemen, some criticisms have been levelled against the suggestions I have given in my paper. The first of them is Mr. Radice's regarding impact. I have taken intentionally a flat rate in order to simplify the design, as has been done by the Ministry of Transport in England who have taken 50 per cent. addition as the impact at the flat rate and have drawn up an equivalent loading curve in 1931 in modification of their recommendations of 1925. That was brought out as a simplified form of the standard loading of 1922 as stated above. You may see on page 289 of my paper that "previous to 1931 bridges of large span had been designed to special loadings, but now the equivalent uniform load curve covers spans up to 2,500 feet". If you see Appendix VI, Col. 3 of my paper, you will find Dr. Waddel's formula for finding out the impact. The impact for a reinforced concrete bridge varies from 25 to 16 per cent. in the case of spans varying from 0 to 100 feet. Road Engineers in India are rarely called upon to design bridges over 100 feet span. The impact variation is also not much. So if we add impact at a flat rate of about 25 per cent. or whatever else that may be decided upon by a committee of experts, the variation will not be much. Moreover, the problem of finding out dynamic effect of rolling loads on highway bridges is a thorny one. Several formulæ have been advocated, but all of them are more or less empirical, and the results obtained from them widely differ and no rational expression for impact has yet been found. All these impact formulæ are provisional and subject to modifications. It is extremely difficult, as I have already stated, to determine this factor on a highway bridge as it depends upon a number of variables. Even in the case of a railway bridge, it is difficult to find out this impact co-efficient correctly but while we have got some sort of standards in their case, we have none such in the case of road bridges.

As regards Diwan Bahadur Ayyangar's suggestion for having 15 units for industrial roads and 8 for non-industrial roads, I should like to say that 15 units is too heavy for road bridges of this country I have stated on page 276 of my paper:—

"Great Britain is a highly developed country, with heavy traffic units and the average intensity of traffic on British Highways is the heaviest in the world and so the minimum loadings for bridges as recognised by the Ministry of Transport of that country cannot be adopted for India. The Ministry of Transport's standard loading is equivalent to 15 units of B. S. I loading with 50 per cent. addition for impact and this unit will be considered as too intensive for road beds of this country, generally, except in a few places of certain provinces, such as parts of United Provinces, Bombay, Madras, the Central Provinces and Chota Nagpur, etc., where roads are mostly carried on unyielding hard sub-strata."

Then, if you look at Appendix III (pages 327 and 328) you will find that I have given particulars of heavy motor vehicles. And at page 310 I have given the details showing the maximum gross load allowed for motor vehicles under the laws of the land. The gross load allowed for a four wheeler is limited to 12 tons. If you take a motor vehicle whose gross

load is 12 tons, you will see that the rear axle load is not more than 8 tons. So we have no reason to fix the standard at 15 units. That is too heavy and we should not adopt it.

Diwan Bahadur N. N. Ayyangar: What is your standard?

Mr. Banerjee: *The gross* loads allowed for motor vehicles in the different provinces are: In Madras it is 12 tons, Bengal 12 tons, Calcutta 12 tons, Bihar and Orissa 7½ tons, Punjab 12 tons to 16 tons which includes 6 wheelers also, U. P. 12 to 16 tons and in Bombay 14 tons. The British Road Traffic Act has limited it to 20½ tons, *i.e.*, for road locomotives, but road locomotives are not in use in India now and will not find favour in future.

If you look at the table given on pages 327 and 328 as Appendix III you will find that the load on rear axle for a 5-6 ton lorry is only 5 tons. Then for trailers, the axle load is limited to 4 tons only. Therefore, my suggestion to adopt 8 units for non-industrial centres and 10 for industrial centres appears to be enough and will serve their functions well till the life time of those bridges. If in the meantime, India develops into an industrial country, she can afford to bear the expenditure which will be necessary for making certain alterations in the design.

Another point has been raised by Diwan Bahadur Ayyangar with regard to my suggestion about raising the working stresses on reinforced concrete bridges. The days for conservatism are gone. Engineering is now an applied science. If we were bold enough to adopt 600 lb. per sq. inch as the working stress while the crushing strength was 1,800 lbs. square why should we not be bold enough to increase the working stresses when actually we find that the strength of concrete has increased by over 300 per cent.?

Mr. Radice: Mr. Chairman and Gentlemen, I think that in view of Mr. Mitchell's proposals that the Indian Road Congress should take steps to draw up a Standard Specification for road bridges, this is not the time or the place to initiate a discussion on questions of standard loadings, impacts, etc., all subjects which may be described as controversial. I think the proper arena for such discussions will be the Committee which I earnestly hope will be established by the Congress, as a result of these papers and this discussion, to prepare a Standard Specification for road bridges.

Mr. Turnbull: I am afraid I do not agree with Diwan Bahadur Ayyangar's statement that the technical supervision and workmanship in this country is of such a low order that these increased stresses should not be allowed. I think you will all admit that the technique of making cement concrete has improved considerably in India in the last six or seven years, and in view of the arguments set forth, I consider that due consideration should be given to the question of increasing the permissible stresses in concrete bridge design to the extent advocated in my paper.

Chairman: The discussion on papers being concluded, may I now ask that the following resolution be passed:—

"That this Congress resolves that the Council be instructed to take all necessary action to enable them to recommend standard loading, allowance for impact, essential specifications permissible stresses, etc., to be adopted by the Congress for bridge designing."

The resolution was duly seconded, put to vote and passed.

Third Day: Saturday, January 11, 1936.

GROUP 8: ROAD SURVEYS AND CONSTRUCTION (PAPERS Nos. 30 AND 31).

CHAIRMAN: COL. G. E. SOPWITH.

Chairman: The next paper is by Mr. F. E. Cormack of the Assam, P. W. D. who unfortunately, could not attend this Congress. The other representative from Assam, Mr. Reidshaw, has also been compelled to leave this morning. Mr. K. G. Mitchell has, however, kindly agreed to introduce the paper.

The following paper was then taken as read:—

PAPER No. 30.

THE CONSTRUCTION OF THE SHILLONG JAINTIAPUR ROAD IN THE KHASI HILLS, ASSAM.

BY

F. E. Cormack, I.S.E., Executive Engineer, Assam.

History.—The district of Sylhet passed into the hands of the East India Company in the year 1765. The Jaintia Perganas in the plains of Sylhet were annexed in 1835 in which year also the Jaintia Hills were ceded by the Raja to the British Government. Assam came into the hands of the British by the treaty of Yandaboo in 1826. Thus the two great valleys of what is now the Province of Assam, *viz.*, the valleys of the Brahmaputra and the Surma were held by the British with no direct communication between them. Consequently the linking up of these two valleys by road has been a matter of considerable importance for over one hundred years.

2. The first record of any European having crossed the Khasi Hills from one valley to the other is that of the journey made in 1824 by David Scott, the Agent to the Governor-General on the North East Frontier with headquarters at Sylhet, when he marched from Sylhet in the Surma Valley to Gauhati in the valley of the Brahmaputra. In 1826 the Siem of Nongkhlao, one of the small native states in the Khasi Hills, was persuaded by Mr. Scott to allow the construction of a road across the Khasi Hills. Work on this road was in good progress under the supervision of Lieutenants Bedingfield and Burlton, when both of these officers were treacherously murdered by Khasis in 1829 at Nongkhlao. Parts of this road are still in use as a bridle path. In 1833 Cherrapunji which, with an average annual rainfall of 460 inches, enjoys the reputation of being the wettest place in the world, was established as the Head Quarters of the Hill districts. For the next twenty years all effort was concentrated on establishing communication between Cherra and Sylhet. In 1864 the Headquarters of the district and the Military forces was shifted from Cherra to Shillong. Gauhati was connected to Shillong by road in 1880 but the problem of connecting Shillong with the plains of Sylhet still remained. Major Briggs of the Bengal Sappers and Miners

first carried out a survey for a road from Shillong to the Sylhet plains in 1862. He ran four different alignments between 1862 and 1864 and then came to the conclusion that the only feasible one lay through Laitlyngkot, Pynursla and Lyngkat.

3. The road now opened follows roughly his alignment up to Pynursla, *i.e.*, a distance of 30 miles from Shillong. There is no record of his having attempted to find an alignment from Lyngkat to Sylhet town and for some reason no work was done on his hill-alignment until many years later. Subsequent surveys were carried out by various officers in the years 1866-67. 1879, 1891, 1892—94, 1896-97, 1905-06. In 1898, work was actually commenced on the alignment made by Mr. Kench of the Public Works Department *via* Laitlyngkot Pynursla to Uthmar in the Sylhet plains. The work was stopped in 1899, started again subsequently by Mr. W. Mc. Sweet and Mr. O. H. Desenne of the Public Works Department and once more stopped, in September 1901, for lack of funds. In 1921 an alignment from Cherrapunji to Bholagunj in the Sylhet plains a distance of 16 miles was surveyed by the writer and an estimate amounting to about Rs. 15 lakhs was submitted. This project also died still-born for the same reason.

4. Finally in October 1928 the writer was deputed to reconnoitre the alignment along which the road has now been constructed.

5. *Preliminary reconnaissance.*—Mr. E. W. Dunn, A.E.S., (retired) had been re-employed in 1927-28 to carry out a general reconnaissance for a possible alignment from Pynursla towards Jaintiapur. Early in 1928 he reported that such an alignment was possible and in October 1928 the writer was deputed on special duty to carry out a detailed reconnaissance in this area with the assistance of Mr. Dunn and to cut a three foot trace along the selected alignment. It should be mentioned here that the road as constructed follows mainly the alignment first traversed by Mr. Dunn and the credit for its discovery rests entirely with him.

6. The detailed reconnaissance was commenced in October 1928 and the cutting of the trace was completed in March 1929. The alignment commences at the 14th mile of the Shillong-Cherra Road, proceeds southwards to Laitlyngkot thence roughly south-east-wards through Lyngkyrdem, Pynursla, Phlang-Poongtoong to Dawki where it crosses the Umngot River and emerges into the plains of Sylhet. From there it proceeds almost due east to Jaintiapur. The line as reconnoitred measured 48·5 miles and as finally constructed 46 miles the reduction being due to minor diversions and the straightening of salients and re-entrants during construction.

7. The laying out of the alignment was carried out as follows. An examination of the one inch ordnance map shewed us a certain number of obligatory points through which the alignment must pass. The various heights of these points were then more or less accurately ascertained on the spot by means of an aneroid. From a consideration of the difference in altitude between these points and the limit gradient, the minimum distance of road between them was arrived at. A very rough line was then plotted on the map, and, with this as a guide the alignment was pegged out by means of a hand clinometer and staff. This was probably the most arduous part of the whole project from our point of view. In the upper section progress was difficult owing to the precipitous nature of the terrain and in the lower part owing to the dense jungle. At the

Lyngkyrdem gorge, at the outset, the only method of progression was by means of bamboo galleries pegged into cracks in the face of the cliff with a 2,000 feet sheer drop below. The laying out of less than a mile of the alignment here occupied nearly two months. The trace was completed at a cost of Rs. 13,568, and fulfilled a dual purpose first to permit us to get the instruments along the alignment and second to give some idea of the material to be excavated. The detailed estimate amounting to Rs. 20,06,411 for the construction of a sixteen-foot wide motor road was commenced in April 1929 and submitted to Government in January 1930. The alignment commences at a height of about 5,500 feet, passes through Laitlyngkot 6,029 feet, Lyngkyrdem 6,000 feet and thence to Jaintiapur about 50 feet, above sea level. The maximum gradient is 1 in 12 and this occurs only in one length of about 1,000 feet over the Lyngkyrdem saddle. In the hill section in order to avoid land-slips, wherever possible, the line was taken on the hill-side where the strata dipped inwards and also on the side least subject to erosion, *i.e.*, that farthest from the direction of the prevailing wind. Owing to the extreme difficulty of the terrain, however, these considerations were frequently out-weighed by the fact that there was only one possible alignment.

8. *General description of terrain, Geology and climate.*—For 37 miles from the junction with the Cherrapunji road the Sylhet road runs through the south-eastern part of the Khasi Hills. This is a terrain of steeply folded spurs and ridges separated by gorges in some cases between two and three thousand feet deep. In the upper section above Phlang-Poong-Toong the country is open with occasional patches of Pine tree and stunted evergreens. In the lower hills the jungle is denser gradually merging into the typical sub-tropical jungle of the Sylhet plains. The remaining 9 miles of the road from Dawki to Jaintiapur passes through very low foot-hills and the alluvial plain of Sylhet.

9. *Geology.*—The whole terrain makes an interesting study for the geologist. It has been subjected to extreme folding in places and some of the older rocks are found super-imposed on those of a very much later geological age. From the upper end the alignment passes over a considerable area of coarse-grained granites followed by schistose rocks and granular quartzite. Some of the latter formed the very hardest rock encountered. The predominant rock to be excavated consisted of hard sedimentary rocks of Khasia greenstone and Shillong trap with, lower down, cretaceous and nummulitic lime-stone and the stratified Sylhet trap

10. *Climate.*—As has already been indicated the climate of these hills during the rainy season is moist. During the period of construction Pynursla, the headquarters of the division, recorded an average of 420 inches per annum, about 98 per cent. of which fell between April and September. This rainfall caused considerable discomfort to the labour force and hampered the progress of work. Thick clouds also impeded the work of surveying and levelling during these periods. In June and July of 1931, Pynursla recorded 27 consecutive days during which visibility was practically nil.

11. *Construction.*—The project for the construction of the road was administratively approved in August 1929 and technically sanctioned in April 1930 and a special works sub-division with headquarters at Laitlyngkot was constituted in October 1929. Shortly thereafter rock-work was commenced at the two most difficult points, namely Lyngkyrdem

gorge and the crossing of the Umngot River at Dawki. Work proceeded slowly at these points until April 1930, when it was shut down owing to an outbreak of Cholera and the approach of the rainy season. On 1st November 1930 the Shillong-Jaintiapur Road (Construction) Division was constituted with headquarters at Pynursla with the writer in charge and a staff of four Overseers and work was commenced all along the alignment.

12. *Lyngkyrdem Saddle.*—In order to reach the Lyngkyrdem plateau and thence the valley of the Umngot river from the valley of the Umrew River it was necessary to take the alignment over a knife-edged saddle about 500 feet long with a sheer drop of over 2,000 feet, on either side. This was known as the Lyngkyrdem saddle and was, perhaps, the most important point in the alignment as, had it not been possible to take the line over this saddle, it would have been necessary to add from ten to fifteen miles to the length of the road. As may be understood, the construction of the road at this point presented considerable difficulty. The summit of the saddle dips very considerably below the summits of the two spurs which it connects. In addition, the alignment beyond the southern end of the saddle runs along the face of the sheer Lyngkyrdem gorge already mentioned. In order to minimise rock-cutting at this point it was necessary to keep the road-level as high as possible. To achieve this it was found necessary to raise the level of the road over the saddle very considerably. This was done by carrying the road on double retaining walls throughout the length of the saddle. These retaining walls are over 30 feet high at their maximum. They are constructed of chisel-dressed dry-stone masonry on concrete foundations. The greatest care was exercised in the selection and preparation of the foundations and subsidiary retaining walls were constructed in several places further down the slopes to prevent all possibility of slips below the road. For the same reason care was also taken to prevent the seepage of water below the road and the retaining walls.

13. *Labour.*—The construction of the road throughout was carried out by contract and was distributed among 36 contractors some of whom hailed from as far afield as the Punjab and Afghanistan. The labour force which soon rose to a total of 6,000 consisted of about 70 per cent. Nepalese with Khasis, Sylhetis and Pathans constituting the remainder.

14. *Medical.*—Two hospitals each in charge of a Sub-Assistant Surgeon were provided one at Lyngkyrdem and one at Dawki to look after the health of the labour force. Labour camps were regularly inspected and medicine and attention were provided free. Although there occurred yearly epidemics of cholera and dysentery, and malaria was always with us, the work was never again brought to a stand-still for these or any other reason.

15. *Machinery.*—Pneumatic drills operated by portable air compressors were used in the upper section near Laitlyngkot and in the Dawki gorge. The fullest use was not made of them in the upper section owing to the conservatism of the Khasi contractors and their dislike of any new thing, but, at Dawki the Pathans operated these drills with great success and without their help the excavation in the Dawki gorge and in the anchorage tunnels of the Dawki bridge could never have been completed in any reasonable time.

16. *Excavation.*—Gelignite was the blasting material used throughout and for over two years we used about 2,000 pounds, per month. The fact that there were no serious accidents throughout this time is a

testimony to the value of this material for use with an ignorant labour force.

Excavation was paid for according to classification of material, the verdict of the Executive Engineer being final on this point. We required thirty-two classifications in all varying from soft earth at Rs. 12 per thousand cubic feet to the hardest quartzite at Rs. 120 per thousand cubic feet. This classification involved a great deal of responsibility for the Executive Engineer and was a constant source of friction between him and the contractors.

17. *Masonry.*—Masonry work in the construction of retaining walls (some of which were over 50 feet high), guard walls and culverts was paid for according to quality varying from hammer-dressed dry stone at Rs. 20 per hundred cubic feet to chisel-dressed masonry in cement mortar at Rs. 120 per hundred cubic feet. The Nepali masons imported from Darjeeling were found to be the best craftsmen for all kinds of masonry work.

18. *Bridging.*—Owing to the fact that the alignment in the hill section follows the water-shed wherever possible the amount of bridging in this section is unusually small. From the junction with the Cherrapunji road to Dawki a distance of 37 miles the total length of bridging is 870 running feet only, including the Dawki bridge with a span of 350 feet. This works out at the very low average of less than 24 running feet, per mile. The Dawki bridge of which a description will be given later, is of the stiffened suspension type. All the others in the hill section are either masonry arches or steel girders on masonry abutments.

19. In addition to the above there are 387 cross drains in this section, that is to say, an average of over 10 per mile to deal with the abnormal amount of storm water consequent on the high rain-fall in the area.

20. In the plains section from Dawki to Jaintiapur a distance of nine miles there is a total of 1,525 running feet of bridging, *i.e.*, about 170 running feet per mile, necessitated by the high floods which occur in this region. The bridges in this section are steel girders carried on screw piles. That this amount of bridging is not excessive was demonstrated at the beginning of June this year when the road-bank which is from ten to twelve feet high was overtopped by as much as two feet in many places.

21. *Dawki Bridge.*—Mention may be made here of the Dawki bridge. This is a stiffened suspension bridge with a 12-foot roadway and 330-foot span between girder bearings designed and erected by Messrs. Kumardhubi Engineering Works at a total cost of Rs. 1,84,893. The bridge which is designed to carry a rolling load of 14 tons on four wheels is suspended from eight, two and three-eighths inch, steel-wire ropes, two and three-eighths of an inch in diameter, carried over steel lattice suspension towers and anchored in four tunnels excavated in the solid rock of the hill side. The steel work was fabricated entirely in this country the wire ropes, only, being imported from England. The bridge materials were brought in country-boats from the steamer head at Chattak a distance of 40 miles. The wire ropes each on a 7 feet diameter reel weighed over 4 tons each and the lifting of these to a height of over 100 feet from water level to road level was a matter of some difficulty without mechanical appliances. The anchorage tunnels, which are 50 feet long and 5 feet in diameter at the mouths, widening to 14 feet diameter at the inner ends, were excavated during the rainy season of 1931. The actual anchorages consist of four flat eye bars 34 feet long bolted to a channel

iron grid at the inner end. These were laid and aligned and the tunnels filled with concrete by the end of October 1931, and the erection of the bridge was completed in April 1932.

22. The sequence of erection was as follows. First the suspension towers were erected with their bases in correct position and their tops canted towards their respective anchorages by a calculated amount so that they would be brought truly vertical by the weight of the bridge and roadway. The wire ropes were then attached to anchorages and heaved up to their saddles on the suspension towers. They were tightened to the calculated initial sag and clamped in the saddles. Suspension rods were then fitted and the lower chord of the stiffening girder bolted in position. The trough plates were then fitted and loaded temporarily to bring the span to the correct camber for fitting the upper chord and cross bracings. Rivetting was then completed and the road way laid. The suspension ropes were then brought to the correct catenary by adjusting the suspension rods and finally the bases of the roller bearings of the stiffener were grouted in position at the centre point of their run at calculated mean temperature.

23. *Conclusion.*—The expenditure on the main sub-heads of work was as follows:—

Statement of expenditure on the construction of the Shillong Sylhet motorable road.

(Shillong-Jaintiapur Section, from the 14th mile of the Cherra cart road.)

	Rs.
1. Excavation (cutting earth mixed up with gravel, boulders, sand stone, rock etc.) and embankment	7,38,388
2 Dry stone retaining and guard walls	2,13,620
3. Bridging (Slab drain armco culverts, and bridges other than Dawki Suspension bridge)	2,97,487
4. Metalling	3,63,520
5. Miscellaneous (Side drain, catch water drain, jungle clearing, tree cutting etc.)	1,10,370
6. Other sub-heads (Maintenance during construction, medical treatment of the staff, compensation for fruit trees, graves, etc., temporary bridges, turfing side berms, spurs caution boards, etc.)	1,53,998
7. Permanent Inspection bungalow and Serai, Pynursla ...	63,257
8. Temporary work Establishment	30,030
9. Special Tools and Plant (Compressor, concrete mixer, lorry boats and mars)	58,184
Total ...	20,28,864

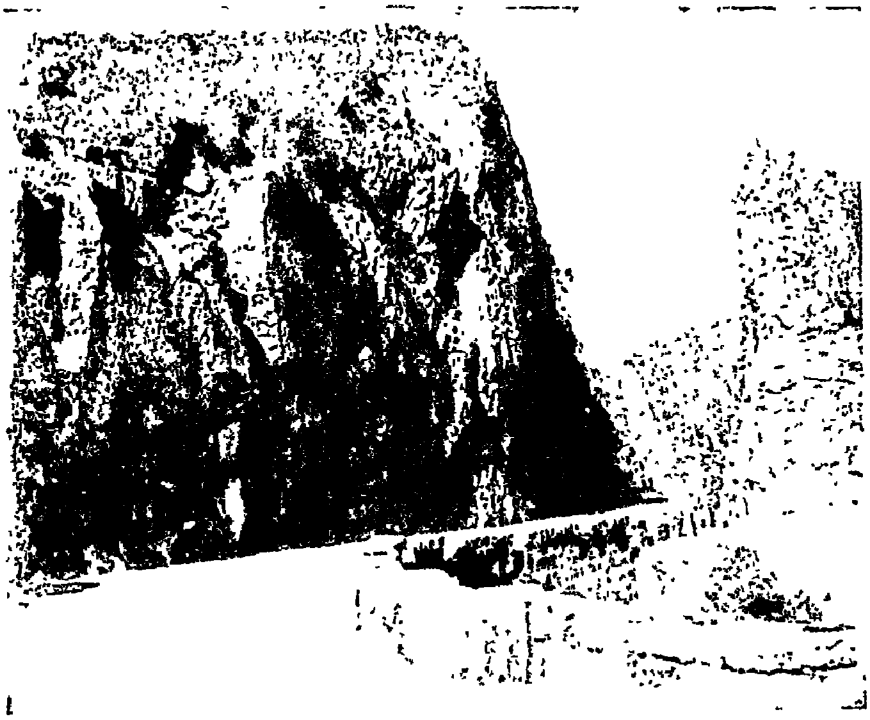
Statement of expenditure on the construction of the Dawki Suspension bridge.

1. Construction of the Dawki Suspension bridge	1,84,893
Total ...	22,13,757

and the average cost works out at approximately Rs. 48,800 per mile.

The cost of Engineering Establishment at site of work was Rs. 1,54,350 *i.e.*, 6·8 per cent of the cost of construction.

The preliminary reconnaissance was commenced in October 1928 and the road was formally opened by His Excellency Sir Michael Keane, Governor of Assam, in March 1933.



Rock cutting at Lyngkerdem Gorge.

On Lyngkyrdem Plateau, 6,000 feet.

Mr. K. G. Mitchell: Mr. Chairman and Gentlemen, I was asked last night by Mr. Reidshaw to introduce this paper on his behalf. Mr. Cormack had intended to be here, but he wired at the last minute that he could not come. Mr. Reidshaw would have introduced the paper on his behalf but he unfortunately has had to leave for Assam, asking me to introduce the paper on Mr. Cormack's behalf.

All I can say is that the paper is thoroughly descriptive of an extraordinarily interesting piece of work. If any of you have any questions to ask, we will make a note of them and send them to Mr. Cormack and his replies will be incorporated in the proceedings in the correspondence section.

The following paper was next taken as read:—

Paper No. 31.

A METHOD OF RAPID ROAD RECONNAISSANCE.

By

Captain W. G. Lang Anderson, R.E., Public Works Department, N.-W. F. Province.

The Problem.

Definition.—Before starting to describe a method of road reconnaissance it is as well to define what is implied by the term reconnaissance as it is so frequently, even in official documents, mixed up with the term survey. To the lay mind this sounds like splitting hairs but the Engineer will readily appreciate that, while a survey implies slow work with mathematical instruments and the preparation of accurate plans, a reconnaissance implies fast work with probably no other instruments than a clinometer, a measuring tape and a note book. Only in the case of some vital defile will reconnoitring methods be abandoned for the laborious process of survey. After the reconnaissance has been completed and the project sanctioned then an accurate survey for the preparation of detailed estimates may be carried out.

2. Thus a reconnaissance consists firstly of traversing the country between the points to be linked by road. This is done usually on foot but may be by horse, camel—an excellent beast on account of its height—or even by car or aeroplane. Secondly of ascertaining the practicability of building a road through the country traversed. Thirdly of choosing the best route to follow and recording it on a map. Fourthly of drafting of a report and an estimate of the probable cost. The first three duties are not very formidable and if conscientiously carried out it will be difficult for any one to criticise the results. The fourth duty is where difficulty arises.

3. *The necessity for speed.*—The time available for making a reconnaissance is almost invariably limited. The Engineer must do the work himself as a comparison of alternative routes can only be made by one person. He himself naturally follows what promises to be the best route. He can send an Assistant to verify that another unpromising route is really what it appears to be. But if the Assistant reports that the apparently unpromising route is in actual fact quite easy, then the Engineer must go over it himself to compare it with the route he has himself travelled. It

is seldom that the Engineer is struck off all other duties and put on to make the reconnaissance only. Thus his normal work piling up behind him hastens his footsteps. But another all too common cause for haste is that the report and estimate are called for at very short notice. Further in savage country such as Tribal Territory the reconnaissance party requires protection. This may vary from half a dozen men as a night guard upto a very large force. In the case of the Wana Razmak road reconnaissance it took two mixed Brigades and 400 South Waziristan Scouts to see the reconnaissance through. Evidently then any time wasted entails heavy expense in keeping a force under arms out in camp.

4. *The Main Problem.*—Thus the problem reduces itself down to how to find the best route through a possibly large intricate tract of country and to make a reasonably accurate estimate of the cost of the route chosen, in a very limited time. With vast experience of road building in a particular type of country the Engineer may be able to make a fairly accurate guess at the cost of a new road, but without that experience he has to work things out somehow or other.

5. The writer's first experience of serious road reconnaissance was when he was called on to reconnoitre a road between Karachi and, that illfated place, Quetta. (The shortest route found was about 425 miles and in all a distance of a little over 1,500 miles was covered in the course of 2 months reconnoitring. Foot, horse, camel, car and six-wheel lorry were all used in the process. In one case swimming had to be resorted to and on another occasion aeroplanes came out, though that was unnecessary, to find the reconnaissance party, which had failed to turn up where it was expected). Having received one's orders the obvious thing was to look up the "book of the words" to see how one should set about such a reconnaissance. One book after another was consulted but all completely ignored the subject—an amazing fact when one considers the thousands of miles of roads in India. There was no time to get books from abroad and in any case one did not know what book to write for. The only alternative was to evolve some system of working for oneself. It is that system which is described below and which has been amended from time to time on subsequent reconnaissances and found to be reasonably satisfactory when tested by the results of actual road construction. The system is particularly applicable to hilly country but is also suitable for the less interesting and easier plains.

PRELIMINARY.

6. *Information required.*—Before the Engineer can do anything about the reconnaissance he must be supplied with certain information which can be epitomised in the words "WHERE, WHAT, WHEN?". As a rule before a new road project reaches the reconnaissance stage there has been a good deal of discussion amongst the various authorities concerned. Whilst those authorities may have reached general agreement as to the desirability of the road there is frequently considerable vagueness as to what is really intended and individual authorities may have quite divergent ideas of what the actual proposal is. Opinions must be obtained and correlated and clear cut definite instructions issued. Alternative instructions may be issued in which case the Engineer must state in his report which he considers the better. Similarly the Engineer may put forward proposals outside his instructions but these must be supported by very sound Engineering reasons. Definite instructions are, however, essential.

7. WHERE is the road to begin and end? which places on the general route are to be touched by the road and which avoided? It may be necessary to exclude certain places in the alignment so as not to conflict with Railway interests, in the case of Civil Roads, and for tactical reasons in the case of Military Roads.

8. WHAT type of road is to be built? The following details are required to decide this question:—

(*a*) The normal width.

(*b*) What traffic it is intended to carry? To a minor extent this affects the radius of curves but it is particularly important in relation to gradients. A road over which motor traffic can travel with ease may be far too steep for economic bullock cart traffic.

(*c*) Extent to which to be bridged. Whether fully bridged throughout? partially bridged upto say 20 feet spans? or unbridged? Obviously this may affect the alignment enormously as in the case of an unbridged road it may be necessary to make a wide detour to avoid a gap which can be crossed only by a bridge.

(*d*) Whether to be metalled, shingled, or natural surface? This also may materially affect the alignment.

(*e*) Miscellaneous information as to buildings, camping grounds, water supplies etc., etc.

9. WHEN the report is required? and WHEN the road is required? If the report is not required for several months then the reconnaissance may be deferred till the climatic conditions are suitable. This does not necessarily mean suitable to the comfort of the reconnaissance party, though that should be considered if possible. In the case of a road over high passes the length of time during which it is free from snow may be of vital importance. Similarly in lowlying country the volume and extent of floods have a very great bearing on, what may be termed, the "design" of the road. Thus the reconnaissance should, if possible, be timed so that as much information as possible can be collected concerning the climatic conditions.

"WHEN the road is required" is also of importance particularly in the case of Military roads. If the road has to be pushed through in one season not only may the cost be affected, but an inferior alignment may have to be adopted.

10. *Preliminary work in the office.*—Armed with the above information the Engineer can make his preparations for the reconnaissance, and the first thing to do is to study the maps. If there are no maps of the area, then one must collect as much information as possible from people who have been through the country; but in India there are excellent maps of most areas through which one is likely to have to build a road. In the case of a long road, say one of over 50 miles, it will pay first to study a small scale map (one-fourth or even one-sixteenth of an inch to a mile) so as to get a clear idea of the general features of the country, and then to study the largest scale map available. In the case of a short road only the large scale map need be consulted. The largest scale of map available will probably be the one-inch to a mile. The maps should be studied from two points of view—firstly to ascertain possible routes for the road and secondly to mark out areas through which it will be difficult to take the road. The latter is important as it limits the area to be studied on the ground and also enables one to work out the shortest marches which will cover that area.

11. Having selected certain general routes or areas as promising the next thing to do is to mark ruling points and these consist of the following:—

(a) *Places* which according to one's instructions must be on the route selected.

(b) *Passes.*—In hilly country, unless a road is following a valley, it almost invariably goes from one pass to another. The heights of passes are generally given on a map and other spot levels are shown. By a study of these and the contours it will frequently be possible to judge whether it is a practical proposition to take the road over a certain pass or not. Even if grades up to say one-in-fifteen are permissible it is unlikely that the road can in actual fact climb more than say 200 to 250 feet in a mile, as physical features almost invariably force one to put in level stretches or even short descents in what otherwise would be a steady climb. Evidently then, dividing the difference in level in feet by 200 to 250 gives one the length in miles of road necessary to reach a certain pass and an estimate of the development necessary to fit the road on the ground. Very occasionally it may even be necessary to climb higher than the pass itself in order to reach it if the country immediately below the pass is exceptionally broken. This was so in the case of the Wana Razmak Road where it had to climb 500 feet higher up a mountain side than the Tiarza Narai (Pass) in order to reach that point.

(c) *River crossings.*—Probably good or probably bad sites for bridges or causeways can be spotted from the map. For instance one frequently finds several nullahs spread over a plain converging to form one main stream. Evidently some point at or below the confluence, affording one crossing, would be better than a higher site which necessitated several crossings.

(d) *Places which must be avoided* such as swamps, precipices, graveyards, buildings, valuable agricultural land, etc.

12. The above are the main considerations governing an intelligent study of the map and many other minor considerations will suggest themselves to the reader. The main point is that a very careful study of the map and the memorising of the features one is likely to encounter will save one a great deal of aimless wandering about on the ground. A road however cannot be sited entirely from a map and in respect of maps one further point is perhaps worth mentioning.

13. The Survey of India plane tablers are extremely accurate and any upto date map can be relied upon, but the weight of the hand varies with individuals. Thus one sheet may show the contours lightly giving the impression of easy country whereas an adjacent sheet may show the contours heavily giving the impression of difficult country. In actual fact the very reverse may be the case. Thus while the position and heights of contours may be taken as correct, little reliance should be placed on the general impression created by colour. After studying his maps the Engineer is in the position of knowing where to go and what to expect, but it still remains to devise a simple method of recording what he will see, and of converting the results of his labours into the terms of hard cash.

14. For the purposes of this paper it will simplify matters to consider a road of the following specification:—

(*a*) Formation, 20 feet wide.

(*b*) Two side drains or one side drain and a catch water drain, each 3 feet wide on the top.

(*c*) Nine inches Soling, 13 feet wide.

(*d*) Six inches metalling, 12 feet wide (thus giving a berm each side of 4 feet).

(*e*) Land width to be acquired 60 feet.

(*f*) The road to be fully bridged throughout with bridges 18 feet wide in the clear.

(*g*) Ruling gradient to be 1 in 20.

(*h*) Maximum gradient for not more than 300 feet and preferably only on straight sections, 1 in 13.

(*i*) Minimum radius of bends 35 feet.

15. The country to be traversed will be taken to be the foothills of the N.-W. Frontier of India, *i.e.*, hard earth mixed with stone capable of standing vertically when cut. In places bare hard rock requiring blasting will be met with and frequently there will be stretches of earth mixed with outcroppings of rock or very large boulders requiring blasting. On level sections the earth will be clay with or without a mixture of small stones. It is assumed that the rates one will have to pay for work are known fairly accurately. It is also assumed that the reconnaissance is to be rapid without time for digging trial pits.

16. Probable costs should be assessed under the following main heads:—

(*a*) Formation.

(*b*) Soling and metalling.

(*c*) Bridging.

(*d*) Land Acquisition.

(*e*) Miscellaneous—*e.g.*, labour camps, water supply, special tools and plant, etc.

Overhead charges for establishment, audit, etc., are added subsequently on a percentage basis.

17. *Formation.*—The excavation necessary will vary according to the slopes of the country, involving side cutting from level up to say 45°. For side slopes over 45°, which are very rare, special calculations must be made. It is very necessary that the soling of a road should be on solid earth, wherever possible. If it is on made earth uneven settlement is bound to take place even if an allowance is made for it, and heavy expense in regarding will be entailed after a very few years. Thus the minimum width of side cut will be the width of the soling *plus* the width of the berm *plus* the width of the top of the inside drain in this case, 13 feet *plus* 3½ feet *plus* 3 feet, giving a total of 19½ feet or say 20 feet, to allow for inaccuracies.

18. The types of cutting can be classified into a few simple classes say as follows:

(*a*) Hard rock requiring blasting.

(*b*) Soft rock or hard conglomerate requiring pick and crowbar.

(c) Hard earth with large boulders requiring occasional blasting but chiefly pick and shovel.

(d) Hard earth and stones requiring pick and shovel.

(e) Soft earth.

19. One can of course have a combination of the above classes which must be estimated on a percentage basis, but probably about five classifications are sufficient for the purposes of making up cost tables. A typical cost table for say item (d) above "Hard earth and stones requiring pick and shovel" would be as follows:—

Side Slope (in degrees).	Length of side cut.							
	50′	100′	200′	300′	400′	500′	1000′	½ Mile.
Level								
3								
5								
7								
10				A				
15								
20								
25			B					
30								
35								
40								
45								

20. Side slopes below 3 degrees would be taken as level. Those between any two side slopes given in the table would be taken as the higher of the two. A above would be the cost in rupees of a side cut 300 feet long in a side slope of 10°—B above, a side cut of 200 feet length at 25° and so on.

21. Supposing on a length of 500 feet on an average side slope of 15° it was considered that while the bulk of cutting would be in "Hard earth and stones" 10 per cent. of it might be "Hard rock" requiring blasting then one would take the costs as follows from the two tables:—

450 feet (90 per cent. of 500 feet) as hard earth at 15°.

50 feet (10 per cent. of 500 feet) as hard rock at 15°.

22. It is evident then that these tables, which can easily be compiled by any junior draftsman, afford a very rapid method of estimating the approximate cost of formation. Their use in the field will be described later.

23. *Soling and metalling.*—Once the stone is delivered at site the cost of these should not vary very appreciably from mile to mile. Carriage to site and the nature of the stone collected will however affect the cost very considerably. Tables should therefore be prepared giving the costs of soling and metalling a mile of road for varying leads from "at site" upto say two miles—

(*a*) When stone has to be quarried,
(*b*) when nullah boulders are available,
(*c*) when carriage is by pack animal,
(*d*) when carriage is by cart or lorry thus:—

	Length of lead.						
	At site.	100′	200′	300′	400′	½ Mile.	etc.
Quarried Stone — Pack			Costs.				
Quarried Stone — Cart							
Nullah Boulders — Pack							
Nullah Boulders — Cart							

Such a table also, given the rates, can be compiled by any draftsman.

24. *Bridging.*—Bridging can conveniently be divided into three classes:—

(*a*) Culverts upto 20 feet clear span.
(*b*) Minor bridges 20 feet to 100 feet length.
(*c*) Major bridges over 100 feet length.

It will usually be known beforehand what type of bridge will normally suit the conditions of the country to be traversed. Any abnormal bridge site will need special consideration and the reconnaissance may have to be halted while a local detailed survey is made; but for the normal type of bridge to be used costs can invariably be found of existing bridges under similar conditions and these costs be noted down at a rate per foot run in the case of (*b*) and (*c*) above (*i.e.*, bridges over 20 feet span).

25. *Culverts* however do not vary in cost proportionately to span as the height of the abutments may become the ruling factor in cost. For instance a 4 feet span culvert with abutments 12 feet high may cost more than a 12 feet span culvert with abutments only 4 feet high; but the dimensions of an abutment of a given height will not vary appreciably with the span up 20 feet.

26. Thus one may take a general type of abutment say with wing walls at 45 degrees to the face and sloping down at 45 degrees and work out the costs for various heights. Similarly one can work out the costs of reinforced cement concrete slabs varying in thickness with the gap to be spanned, and including hand rails etc. Combining these two one arrives at the following table which can be compiled by a draftsman. Very careful detailed estimating is not required. Rough details for obtaining costs will suffice.

Culverts.

Height of Abutment (in feet).	Clear Span in feet.									
	2	3	4	5	6	8	10	12	15	20
2										
3										
4										
5			Costs.							
6										
8										
10										
12										
15										
20										

27. *Land Acquisition.*—A list should be prepared showing the cost of acquiring land of various classes. The land width being fixed (60 feet in this case) all that is required is a list of lengths and cost under each class.

28. *Miscellaneous.*—The cost of miscellaneous items can be worked out at leisure when the report is being drafted but during the progress of the reconnaissance notes should be made to refresh the memory in particular as regards the location of stone, shingle, sand and water.

29. In addition to the tables illustrated above the reader will readily appreciate that others of a similar nature may be necessary according to circumstances. For instance tables of costs of embankments of varying heights and lengths might be useful, or again, tabulated costs of jungle clearance. The main object of these tables is to enable the Engineer to read off the cost of certain work at a glance and avoid all detailed calculation in the field as far as possible. A few minutes work in the evening in camp

will tell one the probable cost of the route traversed that day. One may then be in a position definitely to abandon that route in favour of an alter native route traversed previously. These tables should be pasted on to some leaves of the Field Book.

30. *The Field Book.*—Armed with the above information, the Engineer is in a position to estimate costs very rapidly. It remains to devise a simple method of recording the results of his investigation. A continuous narrative is difficult to follow and the abstracting of information from it not easy. Some form of tabular statement is required in which all the information collected can be recorded with a minimum of writing. A suitable field book has, therefore, been devised and a specimen double page is shown at the end. It can be of any convenient size to go in a pocket. This is important otherwise one may put it down and forget it and after a laborious walk back find it has been eaten by a ruminative "*bail*". A description of the use of this field book comes more appropriately later when the field work is being considered.

31. *Equipment, and personnel required.*—The following is the equipment required by one Engineer doing the reconnaissance. Camp equipment is not included as that of course will vary with the conditions—

(a) Maps on the largest scale available which will probably be one inch to a mile. A minimum of two sets is required—one for carrying around in the field and marking the route traversed, and one for making a fair copy record in the evening in camp. It is best to have a spare set as well.

(b) A map measurer, and one inch scales.

(c) Clinometers. Two in case one gets lost or broken. The most satisfactory has been found to be the circular clinometer reading in degrees upto 45°. The pendant clinometer is an irritating instrument in a wind and is then not sufficiently accurate. The Abney level is unnecessarily accurate. The conversion from degrees to slopes when judging gradients is given by the formula—

Slope $= \frac{\text{Angle}}{60}$ *e.g.*, a 3° gradient is equal (near enough) to slope of $\frac{3^\circ}{60} = \frac{1}{20}$.

(d) Six light sighting poles 12 feet long and painted with alternate black and white bands 1 foot wide. On each pole is a cross piece of thin board 12 inches by 3 inches painted white with a horizontal black line. This cross piece should be fixed at the height of one's eye above the bottom of the pole. On the top of the pole should be a small red flag. This enables the pole to be picked up by the eye easily in undergrowth and also prevents the cooly erecting it upside down.

(e) A prismatic compass. This is sometimes necessary in order to resect one's position on the ground.

(f) A level and staff and a plane table in case any detailed survey work is necessary. Also two 100 feet metallic tapes. These are lighter to carry about than chains.

(g) A pick and shovel for testing soil and rock.

(h) A pair of field glass.

(*i*) A camera and good supply of films. This is very useful for refreshing one's memory and illustrating the report.

(*j*) A strong umbrella.

(*k*) A supply of thin pins for pricking positions on the map.

(*l*) Four copies of the field book each complete with tables pasted in.

(*m*) A copy of the schedule of rates of work in case any detailed estimating is necessary.

(*n*) A supply of stationery, pencils, ink, pens, India rubbers and pen-knives.

(*o*) A horse. The work is most exhausting and a horse to ride to and from camp is a most welcome asset.

(*p*) Six coolies carrying the sighting poles. Four is the absolute minimum. One at the foresight, one at the back sight, one at the observing point and one walking with the Engineer for side slopes. In addition it will save time to have one man going on to a forward position and one man spare for miscellaneous duties.

(*q*) A Subordinate is also a useful asset for booking observations, etc.

32. Finally, before going out in the field. one other calculation should be made. On a hill road many of the minor curves and bends cannot be shown accurately on a 1 inch map. Thus if one runs a map measurer over the road the distance registered will be appreciably less than the actual distance on the ground and this difference may amount to from 5 per cent. to 15 per cent. A 1 inch map, showing a road running through country similar to that to be traversed, should be chosen and this difference definitely be assessed on a percentage basis over as long a length as possible. Several trials should be made so as to obtain an accurate average figure. This percentage will then be applied for correcting distance measured on the map in the field.

FIELD WORK.

33. *Traversing the route.*—When he starts out the Engineer will have a fairly clear idea of the main route that he expects to follow, though unexpected difficulties of the terrain may force him to alter his plan. He starts off at some fixed point, frequently a bend in some existing road. From there on he must religiously walk over the actual line on the ground that the road will eventually follow. Occasionally he may be able to go from one shoulder of a hill to the next if the grade for the road round the hill side between the two points is fairly level but, even so, it is usually easier to follow round a contour than to go down into a small valley and up again. In every case, however, he must obviously stand on the actual site where his sighting pole has been set up. This is arduous walking if the country is rough and rocky, and a mile an hour, including the time spent on booking and taking side slopes, is quite good going. In the following paragraphs no attempt is made to go into the pure technicalities of road construction such as the method of laying soling, quality of metal to be chosen. the siting and design of bridges, etc., etc. Such subjects would require a complete volume to themselves and are in any case beyond the scope of this paper. All that is attempted is to describe how to carry out

the reconnaissance of the road assuming that the reader has a full technical knowledge of actual road construction.

34. The *Modus operandi* is as follows:—

Assume that the first ruling point for which the Engineer is making as a col a certain height above the starting place. If the col is in sight he should immediately take its elevation with the clinometer. If this is 3 degrees ($\frac{1}{20}$) or less, he can start off along the hill side chosing what appears to be the most suitable route. If the col is not in sight, or if the elevation is over 3 degrees he must study the country and the map and select some intermediate visible feature by attaining which he may hope to attain the col. That feature then becomes his first ruling point. It should if possible be distinctive and its elevation must be 3 degrees or less.

35. The Engineer then sends a coolie forward with a sighting pole to some point on the hill side, say 100 yards distance, which is on the average elevation of his first ruling point. He checks the man's position with the clinometer and walks forward to that position leaving another coolie with sighting pole at the starting place. Having arrived at position one he checks the depression back to the starting point and sends a third coolie forward to position two which he selects. He then calls in the coolie at the starting point, moves to position two, checks back to position one, sends a coolie on to position three, and so on.

36. It has been assumed that in selecting his positions the Engineer has not been affected by natural obstacles. When, say a cliff, has forced him to adopt a flatter gradient than the average elevation of his ruling point then he must at the first opportunity put in a stretch at a steeper gradient in order to regain the height lost. Similarly when he has put in stretch at a steeper gradient than the average elevation of the ruling point, then he can probably afford to chose the next stretch using the easiest going (from the point of view of the work involved) at a lesser gradient or even on the level or down hill.

37. One point however is most important. Frequently as he goes along the hill side, the Engineer must check up the elevation of his ruling point. If he finds that elevation increasing then he knows that he is not gaining height as he should and he may never attain his ruling point. There is nothing so heart breaking as to find, after an hour's laborious crawl along a rocky hill side, that the ruling point is 30 feet above one's head. The very steep and rocky valley leading upto the Kangwarai Narai on the Wana Fort Sandeman Road had to be traversed six times before a probable alignment was found and finally its practicability was checked accurately with a level.

38. What applies to climbing to a col equally applies to descending from it except that matters are reversed. The periodical sights taken to the ruling point must show that the depression is not increasing otherwise one will land up above the ruling point, and it is no easier to take a road suddenly down 30 feet than up 30 feet. The famous incident of the mountain railway which missed its objective, owing to faulty levelling, by 200 feet and was completed by a system of lifts, cannot be copied in road construction! The necessity of checking on one's ruling point may appear to be laboured but it is most astonishing how in practice one loses height when climbing and gains it when descending inspite of the extra distance afforded by the re-entrants and shoulders of the hill sides.

39. In conjunction with choosing an alignment to give suitable gradients as above one must also consider curves and bends the object, of course, being to get as straight a road as possible. This is largely a matter of judgment by eye and it will seldom be necessary to resort to measurement, when pacing or a rough check with a tape will usually suffice. All sharp bends of say under 60 feet radius should be put in on the level. Not only does this permit of cutting the corner back at a later date, but it also helps traffic. The level portion acts as a natural brake on traffic descending, and compensates for the extra energy required in turning a corner in the case of ascending traffic.

40. As the Engineer goes forward he must mark accurately on the map the route he has followed. With a fine pin he pricks the position of his starting point and, as he reaches them each succeeding ruling point. The pin holes should be ringed and numbered serially and the route followed between them marked in pencil (not indelible, as a spot of rain will make a large smudge). The numbering is done 1A, 2A, etc. Where a second alternative route is followed it should be marked 1B, 2B, etc., and a third route 1C, 2C, etc. This makes for very easy reference, (Route A, Route B etc.) when subsequently writing the report.

41. The Engineer should also mark each of his ruling points on the ground with a heap of stones or earth. This enables him to return if necessary to a certain point and also may help the eventual constructor of the road to follow his alignment easily.

So far the choice of alignment as regards grades and bends and the recording of the alignment chosen has been considered only. The method of recording the work entailed will now be described.

42. *Formation.*—As he walks over the route the Engineer should take the side slopes with his clinometer. Where the side slopes are fairly uniform over a certain length he takes the average, estimates the distance he has come either by eye or by pacing, judges the nature of the soil to be excavated and enters this information in the field book say as follows (*vide* specimen page of field book at the end).

(*a*) He enters column 1 to show the points between which he is working,

(*b*) *Column 2 he leaves blank*.—This is filled up in Camp in the evening as will be explained later.

(*c*) In column 3 he makes such entries as follows:—

200 yards S. C. 15° H. E.

150 yards S. C. 20° H B.

300 yards L. S. E.

100 yards S. C. 25° H. B. 80 per cent. H. R. 20 per cent.

(*d*) Column 4 is completed in camp.

From time to time the Engineer should total up the petty distances estimated in column 3 and judge whether the total appears by eye to correspond with the total distance covered. Unless there are very obvious errors he should not make any alterations to his entries as a final adjustment is made in camp as will be described later.

43. The varying percentages of rock, boulders, hard earth etc., in the soil are difficult to judge accurately. The look of the ground, as compared with other remembered hill sides on which a road has been cut, will often be a useful guide. Outcropping of rock and the cross sections disclosed at nullahs will also be a great help. Again, a pick driven into the ground will verify that rock, suspected to be near the surface, is in fact there. Admittedly much of this is guess work, but if the Engineer has any experience of the country side the probability is that his errors of estimation will average out.

44. *Soling and metalling.*—Soling and metalling call for little comment. The Engineer naturally tries to locate suitable stone as near the route as possible but he may have to go off the route some considerable distance to find them. Before leaving the route he must mark on the ground the point where he left it. Having found the stone he enters up columns 5 and 7 showing it as either on site or giving the distance and compass point from some ruling point.

Columns 6 and 8 are completed in camp.

45. *Bridging and Nullah crossings.*—A bridge (or causeway) should cross a nullah at right angles if possible. But before reaching the actual crossing it will very frequently be necessary to put in a side cut down the bank of the nullah or the side of the valley. Wherever possible one should always enter the valley going upstream and come out of it going downstream. This will reduce the length of the side cut very considerably. For instance, assume one has to descend 50 feet to reach the nullah bed which slopes at 1 in 100 and it is desired to take the road down at a gradient of 1 in 20. Then entering the nullah bed going downstream the side cut would be 1,250 feet long whereas going upstream it would be only 830 feet long. In the country side contemplated many rivers slope as steeply as 1 in 25, when the disparity in distance would be very much greater.

46. Having selected his site for the bridge or large culvert the Engineer will then try to estimate the waterway required. Natural cuts made by the stream will be good indication. High flood marks should be searched for and local natives questioned if possible. The waterway thus arrived at will be applied to the site of the crossing selected and a span and height chosen suitable to the gap which give a cross sectional area not less than the estimated waterway.

47. In the case of small culverts the size must be judged very largely by eye bearing in mind that money wasted in putting in too large a culvert will frequently be more than saved by having avoided the cost of replacing too small a culvert washed away in a flood. The position of each bridge or culvert is marked on the map with a X and numbered serially X1, X2, etc. The number, type, span and height of the bridge or culvert is entered in Col. 9; Col. 10 being left blank for completion in camp.

48. *Land Acquisition.*—Little need be said about land. The length of land on the width proposed is entered and its class. Cost can be filled in later. In some cases however it may be necessary to acquire more than the required land width, where, for instance, the construction of the road will cause the destruction of a whole field. Rough details of this should be entered in col. 13 under remarks. Similarly if the construction of the road is likely to be commenced shortly particulars of any sown crops, for which additional compensation may be payable, should be entered in the remarks column.

49. *Miscellaneous Items.*—The remarks column should also be used freely for recording any facts seen on the ground which are relevant to the framing of the final estimate and which are essential to the making of various calculations. The following are a few suggested items:—

(*a*) The length and height of probable retaining walls and retaining works.

(*b*) The position of sand and gravel. If these are scarce entailing long leads to bridge and culvert sites and additional percentage on the cost of bridges and culverts may have to be added.

(*c*) The position and approximate quantity of water. This may affect bridging but will certainly affect the cost of consolidating the metalling. Further the exact position of water is necessary so the cost of pumping sets required to deal with probable heads can be estimated.

(*d*) If labour camps are necessary sites for these should be selected. They should never be more than 6 miles apart otherwise too much time is lost going to and from work.

(*e*) Any of the resources of the country, which may bear on the eventual construction of the road, should be noted down.

(*f*) Sketches illustrating any of the entries in other columns should be entered in the remarks column. Likewise if a photograph is taken of any feature a note to that effect should be made in the remarks column. After a long reconnaissance it is often difficult to identify what places have been photographed.

50. Enough has been said above to show that the Engineer on a road reconnaissance has a very full day. The physical exertion is considerable and his eyes must be everywhere, studying the country and judging facts. He will be advised not to prolong it too long as he still has his camp work to do, and, even if he does not fall asleep, there is a heavy strain on the eyes when working after dinner by probably poor artificial light. He will be wise therefore to reach camp not later than 5-0 P.M., have a bath, change of clothes and tea and so keep the last hour or hour and a half of good day light for completing his field book.

51. *Camp Work.*—The work in camp consists of making a fair copy in ink, on a second set of maps, of the route traversed during the day, and then completing the Field book. The distance between ruling points along the route marked on the map should be measured with a map measurer and corrected to allow for minor bends and curves as described previously. These distances should then be entered in column 2 of the Field book. The paced or judged lengths in col. 3 should then be totalled and if this total varies by more than 10 per cent. of the distance given in col. 2 the detailed lengths in col. 3 should be corrected proportionately. Costs taken from the tables can then be entered in col. 4. The next columns to be completed are those under "Bridging", as this requires a careful study of the map and a good light is essential.

52. The catchment areas of over 0:1 mile of all nullahs crossed should be measured up. Using Dun's drainage table (*vide* table attached) one can ascertain whether the waterway allowed for each bridge is adequate or not. This table has been found in practice to be very accurate.

53. In 1932 an exceptional flood took place in Waziristan and the Kirriawam bridge over the Tak-i-Zam had three spans destroyed—a most astonishing event in which 96 foot girders were carried away and thrown up like match sticks on the bank half a mile downstream. The Hinnis Tangi bridge a couple of miles upstream was undamaged though the water just lapped the lower booms of the girders. The cross sections of the flood were calculated and were found to correspond almost exactly with the waterway required according to Dun's Drainage Table.

54. The great advantage of this table is that it avoids all detailed calculation and observation except for the measurement of the catchment area on the map, which is a simple matter. Having measured these the size of bridges shown in the field book should be adjusted accordingly.

55. Culverts are a more difficult matter as the catchment areas are small and ill defined. Further the provision of catchwater drains alters the natural catchment area of a small rivulet. The main point is to provide enough culverts with a total waterway area sufficient to take the whole run off of the hill side that the road is crossing. The area of the hill side above the road can be measured on the map and the total waterway required can be calculated from the drainage table. The total waterway of the culverts shown in the field book must be not less than the calculated waterway. If it is less the size or number of culverts should be increased. As a rule a large number of small culverts will afford better drainage than a small number of large culverts. On an average hill road 5 to 6 culverts per mile are necessary. The size of bridges and culverts having been adjusted as above the cost can be calculated from the tables in the field book and entered in column 10.

56. The completion of the remaining columns in the field book is self evident. It will consist almost entirely of entering up figures from the cost tables pasted in the book, some minor adjustments being necessary occasionally when unusual conditions exist which will have been recorded in the remarks column. A certain amount of detailed calculation will be required in the case of retaining walls the cost of which should then be included in the columns for information. But all items in the nature of general or overhead charges such as labour camps, pumping plants, etc., can be left until the report is being drafted after return from the reconnaissance, as their costs will probably be common to all routes.

57. The costs shown in the field book are then totalled and divided by the total distance shown in col. 2. The Engineer thus has a cost per mile which enables him to make an easy comparison of the various routes he covers from the purely cost aspect. Other aspects of their various merits or demerits will be dealt with in the report.

The Report and the Estimate.

58. On return from camp the Engineer should take one look at his office and one look at the Club bar. Thereafter he should avoid both religiously until he has completed his report and estimate as the change of environment rapidly blots out impressions which one thought were indelibly engraved on one's memory.

59. *The Estimate.*—While the bulk of the estimating has been done in the field there still remains a lot to be done in the office. There is no need to detail these items here as the reader will probably already have appreciated them, and they will certainly be only too apparent to anyone who has just completed a reconnaissance. The grouping of costs into suitable sub-heads, however, requires consideration and the following are suggested :—

(*a*) Road formation including retaining walls, and drains,

(*b*) Soling, metalling and surfacing,

(*c*) Bridges, culverts, and causeways,

(*d*) Land acquisition and crop compensation,

(*e*) Accommodation both temporary and permanent (rest houses),

(*f*) Road side structures—milestones, road signs, road parapets,

(*g*) Water supply.

60. It will be convenient to divide the road up into sections and estimates of the cost of the above items should be given for each section separately. The limits of sections should be fixed by features on the ground, *e.g.*, from one village to another or according to general changes in the nature of the terrain such as plains, foothills, rugged hills, etc. The administrative authority can then if necessary allot money for building the road section by section. To the above costs the following must be added :—

(*a*) Special tools and plant.

(*b*) Work charged establishment.

(*c*) Audit charges.

(*d*) Pensionary charges.

(*e*) Interest charges (if the road is built from a loan).

(*f*) Political charges (in certain tribal areas).

The field book need not be attached to the estimate but should be kept in safe custody for reference and record.

61. *The Record.*—The following is a suggested frame work for drafting the report :—

THE HEADING should state the places which it is intended to connect by road and the data on which the reconnaissance was made. The sheet numbers of the 1 inch maps covering the area should also be stated.

THE OBJECT of building the road should be stated, the type of road proposed, and the reasons proving the necessity of the road. This is also the appropriate place for giving references to any important official letter dealing with the subject.

A GENERAL DESCRIPTION OF THE COUNTRY is a great help to anyone reading the report who is not acquainted with the area. The climatic conditions should be mentioned and the lowest and highest altitude attained. The density of population, their modes of livelihood, any peculiar customs, all help to make the conditions clear and add interest to an otherwise rather stodgy document.

ROUTES TRAVERSED.—A clear statement of each route traversed, with its total estimated cost and length should be given, the routes being referred to as Route A, Route B, Route C, etc. The merits or demerits of each route should be touched on in narrative form. These will be condensed into a tabular comparative statement as described below.

MAPS.—The report must of course be accompanied by a 1 inch map showing the exact alignment of the various routes. If this is rather large and unwieldy it will be advisable also to attach a small scale map for easy reference. It is, after all, only when a very detailed study of the report and estimate is being made that reference to the 1 inch map is necessary.

COMPARATIVE STATEMENT.—The report may perforce run to many pages of foolscap and it will be difficult for one reading it to assimilate the comparative merits of each route reported on. A comparative statement in tabular form summarising these should therefore be given and the following are suggested headings; others may suggest themselves to the reader:—

(a) Length.

(b) Gradients:—heavy, moderate, or light.

(c) Liability to interruption by floods or snow; bad, normal, good.

(d) Climatic considerations:—cool, medium, hot.

(e) Water supply:—plentiful, adequate, scarce.

(f) Economic; whether the route serves a populated area or not?

(g) Political; whether the route will conflict with railway interests or not? How it may affect Indian states or tribal areas?

(h) Strategic and Tactical. This applies only to roads of Military importance.

(i) Engineering consideration—easy to construct, average or difficult.

(j) Capital cost as per estimate.

(k) Maintenance costs—heavy, normal or light.

The above will enable the administrative authority to decide which route to select, that selection being dependent upon which of the considerations, detailed above, may be of importance. The report, however, would not be complete without the Engineer's expression of his own opinion on the subject.

RECOMMENDATION.—In giving his recommendation the Engineer will naturally be guided by professional considerations as it is not his duty to express opinions on subjects outside his own province. It will, however, be fruitless for him to recommend a certain route for purely engineering reasons if he well knows that it will be unacceptable on account of other considerations. Hence while giving due weight to the professional aspect of the case, he must also allow for the other factors affecting it, and should record his reasons in coming to a decision.

The most important point, however, is that the Engineer must give a recommendation and that recommendation must be definite whether it is accepted or not.

TABLE

OF

Waterway area required for catchment areas.

Based on the Dun's Drainage Table.

Catchment area in square miles.	Area of waterway in square feet.				Catch-ment area in square miles.	Area of waterway in square feet.			
	In Hills.		In Plains.			In Hills.		In Plains.	
	120%	100%	80%	50%		120%	100%	80%	50%
·01	2·4	2·0	1·6	1·0	12	888	740	592	370
·02	4·8	4·0	3·2	2·0	14	960	805	644	403
·04	0·0	7·5	6·0	3·8	16	1038	865	692	433
·06	12·6	10·5	8·4	5·3	18	1104	920	736	460
·08	16·2	13·5	10·8	6·8	20	1164	970	776	485
·10	19	16	13	8	25	1296	1080	864	540
·20	38	32	26	16	30	1416	1180	944	590
·30	53	44	35	22	35	1528	1273	1018	637
·40	67	56	45	28	40	1620	1350	1080	675
·50	79	66	53	33	50	1812	1510	1208	755
·60	89	74	59	37	60	1980	1650	1320	825
·80	106	88	70	44	70	2136	1780	1424	890
1·0	120	100	80	50	80	2280	1900	1520	950
1·2	144	120	96	60	90	2418	2015	1612	1008
1·4	168	140	112	70	100	2544	2120	1695	1060
1·6	192	160	128	80	120	2778	2315	1852	1158
1·8	216	180	144	90	140	3000	2500	2000	1250
2·0	240	200	160	100	160	3198	2665	2132	1333
2·5	300	250	200	125	180	3384	2820	2256	1410
3·0	360	300	240	150	200	3564	2970	2376	1485
3·5	419	349	279	175	250	3970	3308	2646	1654
4·0	466	388	310	194	300	4338	3615	2892	1808
4·5	509	424	339	212	400	4998	4165	3332	2083
5	546	455	364	228	500	5532	4610	3688	2305
6	611	509	407	255	600	6036	5030	4024	2515
7	667	556	445	278	700	6504	5420	4336	2710
8	721	601	481	301	800	6960	5800	4640	2900
9	769	641	513	321	900	7296	6080	4864	3030
10	815	679	543	340	1000	7656	6380	5104	3190

The percentage value indicate the relation of the waterway areas in the four columns and have nothing to do with the ratio of run off to precipitation.

Use the 120 percent. column in bare stone covered hills liable to heavy rain storms.

Use the 100 percent. column in hills covered with vegetation.

Use the 80 percent. column for plains close to the hills.

Use the 50 percent. column for plains distant from hills.

These are approximate percentage values, and they may require modification for special conditions and from local experience with existing culverts and bridges.

SPECIMEN DOUBLE PAGE OF FIELD BOOK.

Ruling points.	Distance.	Formation.		Soling.		Metalling.		Bridging.		Land.		Remarks. (e.g., position of gravel, sand and water. Sketches to illustrate entries in other columns, etc.)
		Nature of work.	Cost.	Place available.	Cost.	Place available.	Cost.	Position and Type.	Cost.	Class and Length.	Cost.	
1	2	3	4	5	6	7	8	9	10	11	12	13
S P to 1 A												
to 2 A												

Draw this line after all entries up to point 1 A are complete.

Suggested abbreviations:—

S. P. = Starting point.
S. C. = Side cutting.
T. C. = Through cutting.
L. = Level.
E. = Embankment.
J. = Jungle clearance.

H. R. = Hard Rock.
S. R. = Soft Rock.
H. B. = Hard earth with boulders.
H. E. = Hard earth with stones.
S. E. = Soft earth.
R. = Rock requiring quarrying.

B. = Boulders.
G. = Gravel.
S. = Sand.
W. = Water.
C. = Culvert.
etc., etc.

Capt. W. G. Lang Anderson: After so many interesting papers read and discussed, I have nothing to add to my paper in introducing it except to point out the importance of road reconnaissance. Before you can make a survey of a road, you must have reconnaissance; otherwise, you waste a great deal of your time. Furthermore, on the reconnaissance is finally based the alignment of your road. If you build a building in a wrong place, you can perhaps make use of it for some other purpose. If you build a building of wrong size, you can later on alter it. But if you put a road in the wrong place, it is there for ever. Buddhists roads in the Frontier and the Roman roads at home are examples of this. You cannot wipe them out. That is all I have to say.

There was no discussion on the two papers (Nos. 30 and 31) in Group 8.

Chairman: I should like to thank the authors of these papers for their valuable contribution and I hope you will all join me in doing so.

The Congress then dispersed.

An account of the tours and other functions of the Second Indian Roads Congress will be found at the Appendix to these Proceedings.

APPENDIX.

TOURS AND OTHER FUNCTIONS HELD DURING THE SECOND SESSION OF THE INDIAN ROADS CONGRESS, BANGALORE, JANUARY 1936.

SUNDAY, JANUARY 5, 1936.

The Congress assembled at Queen's Statues (Bangalore) and proceeded to inspect a number of roads in and round Bangalore. A visit was paid to the Municipal store yard on Magrath road and members inspected the Bitumen Emulsion Plant and "Nofrango" work there. Examples of the latter were also inspected at Austin Town (Municipal housing scheme for the poor) and elsewhere.

The thanks of the Congress are due to Mr. W. H. Murphy, Executive Engineer, Bangalore Civil and Military Station for a most interesting morning. The notes circulated by him are reproduced below.

NOTES ON ROADS IN THE BANGALORE CIVIL AND MILITARY STATION.

1. *Sydney Road.*—Carries heavy bullock cart and motor traffic. Metalled with 3" coat of metal in 1913-14, 1916-17, 1919-20, 1920-21, soling and metalling provided again in 1922-23, metalled in 1924-25, resurfaced with 1½ inch coat of metal in 1927-28, and hot spramex dressed in August 1928, resurfaced again with 1½ inch coat of metal in 1932-33 and hot spramex surface dressed in the same year, spramex emulsion dressed in 1933-34 and Texaco emulsion dressed in 1934-35 and being treated in January 1936 with a 2 inch coat of premixed metal chips and emulsion—work actually under progress and inspected by delegates. This is a very good example of class I road in the station which carries heavy bullock cart and motor traffic both ways.

2. *South Parade.*—From St. Mark's road to Brigade road.—Carries heavy motor traffic and light bullock cart traffic. Class II road. Last remetalled in the year 1915-16, has no soling and only about 4½ inch thickness of metal altogether. Tarred with Glassgow tar in the year 1917, again in 1919, with Shalimar tar in 1921, and 1924, with Bhadravati tar in 1927 and Bhadravati tar emulsion in November 1929 and lastly hot spramex surface dressed in March 1933. Will be painted with Texaco emulsion when the surface shows signs of wear and needs repainting.

3. *Residency road.*—From Hodsons Corner to Brigade road.—Carries fairly heavy motor and bullock cart traffic. Metalled with 3 inch coat of granite metal in 1917-18 and in 1922-23. Road surface badly worn and was to have been re-metalled in 1928-29, but was spramex surface dressed instead in May 1928, and with Mexican spramex emulsion in July 1933 and patch repaired with emulsion during the year.

A good example of class II road, remetalling saved by application of spramex surface dressings. Will be painted with Texaco emulsion in April 1936.

4. *Domlur road.*—Carries very heavy bullock cart traffic from the brick kilns and from villages beyond Bangalore. A good example of class I road. Metalled in 1913-14, 1918-19, 1919-20, 1922-23, soling provided with a 2" coat of metal in 1925 and a 3 inch coat of metal in 1926-27, hot spramex surface dressed in November 1928 and again in February 1933 and Texaco emulsion dressed in December 1934, and premixed metal, chips and Texaco emulsion 2 inch coat applied to half the width of the road in November 1935. The other half width of the road will be coated with premixed metal chips and emulsion in May 1936.

5. *Main road through Knoxpet.*—A good example of road in poor residential area, class IV road. Road formed and metalled with a 3 inch coat of granite metal in the year 1931-32 and spramex surface dressed in February 1933. Will be painted with Texaco emulsion when surface shows signs of wear.

6. *Old Madras road from Knoxpet road to Municipal Boundary.*—Has no soling but a thickness of about 7 inches of metal. Good example of class I road. Metalled with a 3 inch coat of granite metal in 1913-14, 1917-18, 1922-23, and 1923-24, 1927-28, resurfaced with 1½ inch thickness of granite metal and spramex surface dressed in 1931-32 and again in 1933-34, spramex emulsion dressed in November 1934, when an experimental bit of premixed metalling was carried out and half width of road metalled with premixed metal, chips and Texaco emulsion in November 1935. Remaining half width of road to be treated with 2" coat of premixed metal, chips and Texaco emulsion.

7. *Richards Town main road.*—Metalled with a 3 inch coat of metal in 1915-16 and coated with hot spramex in January 1930, and nothing done since. Other roads metalled the same year and coated with spramex emulsion in August 1934 and nothing done to them since then. These roads have no soling and only 3 inches of metal consolidated to about 1½ to 2 inches in thickness. To be painted with Texaco emulsion when roads show sign of wear.

8. *Haines road and Spencer road junction.*—Where an experiment of premixed granite metal, sand, chips and spramex emulsion was carried out in January 1934. A 2 inch coat of this premixed metal laid on a scarified metalled surface would not consolidate until water was added, with excellent results.

9. *Station road from Cockburn road to Queen's Road.*—Carries heavy bullock cart traffic on one side of the road and motor traffic as well, class I road. Metalled in 1913-14. Granite soling provided in 1917-18 and a 2 inch coat of metal as well, remetalled in 1921-22, 1925-26, 1928-29 and spramex surface dressed in February 1930. About 100 yards of the road was dressed with Trinidad Asphalt which was not a success, it did not last more than a year. Painted with spramex emulsion in August 1934. Owing to the excessive camber, there is much wear on the outside edge of the road, on the side carrying heavy traffic.

Half width of road carrying heavy traffic to be coated with a 2 inch coat of premixed metal, chips and Texaco emulsion in April 1936.

GENERAL NOTE ON BANGALORE CIVIL AND MILITARY STATION ROADS.

Up to the year 1916-17 the Civil and Military Station roads were of ordinary water bound macadam without any kind of soling or tar or bitumen surface treatment. The average thickness of metal on the roads was about 4½ inches. The metal used was broken by hand from the local granite stone into 1½ to 2 inches cubes and a renewal metal coat consisted of a 3 inch coat of metal consolidated in the usual way with local gravel used as a binder.

In the year 1917-18, owing to the large permanent and continued increase in motor and bullock cart traffic as well as the large volume of traffic the roads had to carry during the latter years of the war, when the number of troops in the Station were more than 25 times the present number, many roads broke up badly, particularly those carrying heavy bullock cart and motor traffic. It was then found that the ordinary method of renewal metal consolidation did not stand up to the traffic, when it was decided to provide foundations for roads carrying heavy bullock cart and motor traffic. A soling consisting of quarry waste granite stones measuring about 4″×5″×4″ was laid by hand and packed on Station Road and consolidated in the usual way. A 3 inch coat of granite metal was then laid on the surface and thoroughly consolidated by a steam roller. This method of road construction proved successful and was extended to other roads carrying similar traffic as Station Road. The life of roads treated in this way was found to be double that of those consolidated without soling, but even this treatment was found to be unsatisfactory, as the material binding the metal if not washed out during rain storm was sucked up by tyres of fast moving motor vehicles and had to be frequently replaced during the year which was not only expensive but considerably increased the dust nuisance.

In the year 1917-18 in order to reduce the dust nuisance it was proposed to experiment with tar for surface painting, and South Parade from St. Mark's Road to Brigade Road was selected for the purpose, as the road carried heavy motor car traffic and a small amount of bullock cart traffic as well. The road had been remetalled 1½ years previously and the surface was fairly good. The very best Glasgow tar obtainable was used and heated in large barrels and applied in the usual way with bass brooms. A ½ inch thickness of sand was spread over the tarred surface and rolled by a steam roller and the road opened to traffic immediately after. About 3 weeks after tarring operations were completed the surplus sand was swept off the surface of the road. The road required no attention of any kind for the first year but, had to be tarred at the end of the second year, and since then it was retarred every two years.

In the month of November 1927, three short lengths of road carrying fairly heavy motor and light bullock cart traffic were selected for surface treatment of a hot paint coat of spramex, dressed with ½ inch thickness of granite chips. The work was done by Best & Co., of Madras and was most successful, with the result that, the use of hot spramex surface dressing became general for most of the roads in the Station. The only trouble experienced with this method was, excessive bleeding during the hot months, when the roads had to be very carefully watched

and on the first sign of bleeding, coated with sand, otherwise the spramex would pick up on iron tyred vehicles in long ribbons and the road surface completely destroyed unless repaired immediately. The bleeding generally continued for about 2 years, after which there was no further trouble.

In the year 1934-35, after many months of experimenting with the manufacture of bitumen emulsion, a stable emulsion was produced in the Municipal Workshop prepared from Mexican spramex of 200 penetration and, during that year nothing but this emulsion with a covering of granite chips was used for surface dressing the roads in the Station. The following year, Texaco bitumen of 100 penetration was used for the manufacture of emulsion and now nothing but this emulsion is being used for roads.

As paint coats of hot spramex or bitumen emulsion were found unsuitable for roads carrying very heavy bullock cart and motor traffic, experiments were carried out in the Municipal Workshop with mixtures of metal, sand and bitumen emulsion in various proportions to form a concrete that would stand up to the heavy traffic and as result of this, a method has now been evolved for laying a premixed coat of metal, chips and Texaco emulsion that is easily consolidated into a solid mass. Two short lengths of road were selected for laying this premixed metal on Domlur and Old Madras roads where the incoming traffic is of the heaviest type in the Station. A 100 feet length of half the road width (the half carrying the heaviest traffic) was laid with this mixture in November 1934 and still both the lengths are as good as the day they were laid and it has now been decided to use this method of road treatment for all roads carrying heavy bullock cart and motor traffic. Three long lengths of main roads have been treated in this way for half their widths within the past 2 months. It may be mentioned here that "Texaco" hot application, "Coalfix", "Colas" "Bitumuls", "Socony emulsion", "Colado" and "Mexico road oil" have all been used in the Station with much the same results although it must be said that all these experiments were carried out on a very small scale.

As a result of the experiments carried out in the Station the following methods of road treatment have been permanently adopted :—

No.	Kind of traffic carried by the road.	Method of treatment.	Actual cost per 100 sft.	Remarks.
1	Very heavy bullock cart traffic of not less than 400 carts a day and 100 motors.	Premixed metal of 1½" gauge and ½" granite chips and Texaco bitumen emulsion laid 2" thick consolidated to about 1½" thick on an old metalled road either with boulder soling or at least 6" thickness of metal.	Rs. 7-5-0	The cost includes all labour and materials used for the work including cost of fuel and oil for steam roller. Hire of roller and wages of driver and fireman are not included. Establishment charges are not included but the pay of the supervising mistry is included.
2	Heavy motor traffic and light bullock cart traffic of not less than 100 carts a day.	Two coat painting with Texaco emulsion on a well consolidated water bound road with at least 4½" thickness of metal.	Rs. 3-1-6	Ditto.
3	Light motor and very little bullock cart traffic.	Single coat painting with Texaco emulsion on a well consolidated waterbound road with at least 3" thickness of metal.	Rs. 2-1-4	Ditto.
4	Very little motor traffic in residential areas with no through traffic.	Single coat painting with Texaco emulsion on a water bound road with at least 2" thickness of metal.	Rs. 2-1-4	Ditto.

NOTE.—*Sl. No. 1 above.*—As the experiment was carried out only 14 months ago for the first time, it is impossible to say at this stage how long the road will last but its life may be estimated at 3 years at least, when a paint coat of emulsion may become necessary and may have to be repainted every year or 2.

Sl. No. 2 above.—The life of this road may be taken as 2 to 3 years depending on the amount of traffic it carries. A paint coat of emulsion will then have to be applied every two years.

Sl. No. 3 above.—The life of this road will be from 1 to 2 years, depending on the amount of traffic, after which a paint coat will be necessary every 2 to 3 years.

Sl. No. 4 above.—The life of this road is about 2 to 3 years, after which a paint coat will be necessary every 4 to 6 years.

Details of expenditure for Macadam dressing old Madras Road at Bangalore.

		Rs.	A.	P.
Cost of—				
Metal	7,496 at Rs. 9 per hundred cubic feet	674	10	0
Chips	3,780 at Rs. 15 ,,	567	0	0
Labour	(Actuals as per roll)	394	11	0
Emulsion	9,989 at Rs. 0-5-3 per gallon	3,277	10	3
Steam Road Roller and other Miscellaneous charges		197	4	10
		5,111	4	1
Area covered was 70,608 square feet ∴ cost per hundred square feet was		7	4	0

Hosur Road.

Cost of—				
Metal	6,656·5 at Rs. 10 per hundred cubic feet.	665	10	0
Chips	3,156 at Rs. 16 ,,	504	15	0
Emulsion	8,876 at Rs. 0-5-3 per gallon	2,912	7	0
Labour	(Actuals)	281	0	0
		24	0	0
Steam Road Roller charges		162	9	10
		4,550	9	10
Area covered was 62,150 square feet ∴ cost per hundred square feet was		7	5	0

Domlur Road from South-East corner of entrenchment to boundary

Cost of—				
Metal	3,217·5 at Rs. 9 per hundred cubic feet.	289	9	0
Chips	1,470 at Rs. 15 ,,	220	8	0
Labour	(Actuals)	143	8	0
		6	0	0
Emulsion	4,176 at Rs. 0-5-3 per gallon	1,370	4	0
Steam Road Roller charges		83	13	0
		2,113	10	0
Area covered was 29,026 square feet ∴ cost for hundred square feet was		7	5	0

Domlur Road from Road Agaram Barracks to entrenchment.

Cost of—				
Metal	1,670 at Rs. 9 per hundred cubic feet.	150	5	0
Chips	964·5 at Rs. 15 ,,	144	11	0
Labour	(Actuals)	90	15	6
Emulsion	2,630 at Rs. 0-5-3 per gallon	862	15	6
Steam Roads Roller charges		83	13	0
		1,332	12	0
Area covered was 18,190 square feet ∴ cost per hundred square feet was		7	5	0

Brief specification of premixed bitumen Macadam work.

The surface of the road to be treated, after being thoroughly cleaned with bass or wire brushes, is painted with a thin coat of Texaco emulsion, about 60 square feet per gallon. Ungraded, screened granite stone metal of 1½ inch gauge is then mixed with Texaco emulsion, by hand, in the proportion of 100 Cft. to 30 gallons and spread to a thickness of about 1½ to 1¾ inches and lightly rolled, after which clean ungraded granite chips of ½ to 1/16 inch gauge is mixed with Texaco emulsion, by hand, in the proportion of 100 cubic feet to 60 gallons and spread on the surface of the rolled metal. The metal and chips are then thoroughly rolled until properly consolidated and, the following day the surface of the road is swept off surplus chips, slightly watered and painted with Texaco emulsion, 13 square feet per gallon, covered with a thin coat of ungraded granite chips of ½ to 1/16 inch gauge and rolled until thoroughly consolidated. The surplus quantity of chips are swept off the surface a fortnight after completing work and used for patch repairs to other roads.

DETAILS ABOUT THE BITUMENS EMULSION PLANT AT THE GOVERNMENT INDUSTRIAL AND TESTING LABORATORY, BANGALORE.

Cost of Premier Colloid Mill, the machine used for the manufacture of the emulsion, Rs. 3,100. It is a 10 inch size mill with stainless steel and feseelised nickel fittings. It is capable of an output of 200—250 gallons of emulsion per hour.

Cost of the building Rs. 1,400.

Cost of other equipment like bitumen boiler, hot water boiler, mixing tank, pump for pumping the emulsion and storage tanks Rs. 5,500.

Establishment.—One Foreman on Rs. 100 per month, one clerk and store keeper on Rs. 30 per month. Labourers 8 men.

Production per day of 8 hours=1,000 to 1,400 gallons.

The cost of a 60 per cent. emulsion works out to annas 5/3 a gallon

SUNDAY, JANUARY 5, 1936—*contd.*

In the afternoon, at 2 P.M., the party inspected the following experimental road works carried out by the Mysore P. W. D.

1. CUBBON PARK ROAD.

(A) From Queen Victoria Statue to Fountain Circle.

Length	1,404 feet.
Width	25 feet.
Area	3,919 square yards.

This is in a continuous curve.

Original Surface.—Due to the continuous curve and the heavy motor traffic, the laterite surface had very much deteriorated on the outer side of the curve; longitudinal corrugations had developed, and there were bad ruts and pits at places.

Treatment.—The whole surface was picked and re-formed with the required quantity of laterite so as to form super-elevation on curve and the metal was thoroughly consolidated with water. Over the surface thus prepared, a 2 inch coat of granite metal was given, properly watered rolled and consolidated.

When the road was dry, the surface was painted with Shalimar tar No. 1 at 44 pounds per 100 square feet or 5 pounds per square yard and blindage of chips spread at the rate of 3 cubic feet per 100 square feet of surface with hard graded granite chips (60 per cent. to be ¾ to ⅜ inch and 40 per cent. to be ½ to ⅛ inch and no material to be less than ⅛ inch.)

Cost of Treatment.—Patch repairs with laterite and the top coat of granite metal cost Re. 0-4-7 per square yard. The tar coating cost Re. 0-5-8 a square yard so that the total cost of this treatment was Re. 0-10-3 per square yard.

(B) From His Highness's Statue to Fountain Circle.

Length	397 feet.
Width	25 feet.
Area	1,138 square yards.

This is in one straight length and is fairly shaded by trees on both sides.

Original Surface.—The old surface was of laterite. A considerable number of pot-holes had developed and the surface was bad.

Treatment.—A coat of hard laterite metal 2½ to 3 inches in thickness, was laid and consolidated. After this had settled under traffic, it was treated with Shalimar tar No. 1 at 44 pounds per 100 square feet and blinded with ½ to ⅛ inch hard graded granite chips (60 per cent. to contain ½ to ⅜ inch and 40 per cent. to contain ¼ to ⅛ inch chips and no material being under ⅛ inch). The chips were spread at the rate of 3½ cubic feet per 100 square feet.

Cost of Treatment—

	Rs.	A.	P.	
(a) Cost of re-coating the surface with laterite and making it ready to receive the tar painting works at	0	6	9	per square yard.
(b) Cost of tar painting inclusive of cost of chips at	0	5	8	,,
The total cost per square yard of treatment .	0	12	5	,,

(C) His Highness's Statue towards the Public Library.

Length	558 feet.
Width	21 feet.
Area	1,417 square feet.

Original Surface.—The old laterite surface was fair for some distance and was very bad at the end.

Treatment.—The surface was picked and formed and given a re-coat of 3 inches of hard laterite metal.

For half the length the surface was given a primary coat of Tarfoid (previously well mixed and diluted with about 50 per cent. of water) at 1/12 gallon per square yard. Twenty four hours after this application, Shalimar tar No. 2 was applied at ¼ to 1/5 gallon per square yard and blinded with hard graded granite chips at 4 cubic feet per 100 square feet (60 per cent. of ½ to ⅜ inch chips, 40 per cent. of ¼ to ⅛ inch chips, and no chip was smaller than ⅛th of an inch.)

The other half length of the surface was treated with Shalimar tar No. 1 at 44 pounds per 100 square feet and blinded with hard graded granite chips; 3 to 3½ cubic feet per 100 square feet graded as above. A month later a second coat of Shalimar tar No. 2 has to be applied at 17 to 18 pounds per 100 square feet; the chips were graded ½ to ⅛ inch.

Cost of Treatment—

	Rs.	A.	P.	
(*a*) Re-surfacing with laterite cost	0	6	9	per square yard.
(*b*) The tarring of one coat with a priming coat for 1st half bit cost	0	8	3	„
The total cost of first half is	0	11	9	„
and for second half with two coats is . .	0	15	0	„

2. The Pettah Lal-Bagh Road.

This is a suburban road 2½ miles in length, subjected to heavy wear on account of bus and bullock cart traffic from and to Hosur in the Salem District of Madras Presidency. To prevent longitudinal ruts, the following trackways with different materials have been laid as an experimental measure, for short lengths, in continuous strips, to study the economy and relative durability of each type.

(*a*) Granite slab trackways (slabs of 4 to 6 inches thick) with one line dressing at top, laid for a length of 2 furlongs at an estimated cost of Rs. 1,000 per furlong.

(*b*) Bituminous Macadam trackways (3 inches thick) laid for a length of 2 furlongs at an estimated cost of Rs. 800 per furlong.

(*c*) Cement concrete trackways (4 inches thick) laid *In Situ* for a length of 220 feet at an estimated cost of Rs. 1,050 per furlong.

(*d*) Pre-cast re-inforced concrete trackways (3 inches thick) laid for a length of 220 feet at an estimated cost of Rs. 1,200 per furlong.

(*e*) Cement (grouted) macadam trackways (4 inches thick) laid for a length of 220 feet at an estimated cost of Rs. 400 per furlong.

In all these cases, the tracks are 2 feet wide and 4 feet 8 inches gauge centre to centre.

Of the above trackways, (*a*), (*b*) and (*c*) are standing well; (*d*) is showing signs of failure at places and (*e*) is already badly damaged.

The bullocks show a tendency to avoid these slab tracks owing probably to the hard surface. To mitigate this, a coat of Spramex has been given on the slabs and the result is fairly satisfactory. Mechanical transport, however, freely uses the tracks which are very durable.

The party then proceeded to "Chamraj Sagar and Water Works", recently constructed for the water supply of Bangalore city and the Civil and Military Station and situated 22 miles out on Bangalore Magadi Road. This road throughout consists of water-bound macadam, the width of road surface being 12 feet. During the last two years the surface has been improved considerably and the berms widened. The milage grant for the road averages Rs. 225 and it has not been found possible to re-metal the surface earlier than once in six years. The traffic on the road is fairly heavy, consisting mostly of heavily laden bullock carts. The reservoir lies amidst charming surroundings in a valley enclosed by low hills.

On arrival the party were entertained to tea, as the guests of His Highness the Maharaja. They were then taken round the Dam, Waste Weir, Filters and Pumping Station.

The Masonry dam which impounds the water is 115 feet above the bed of the river. Its present storage capacity is 2,560,000 million cubic feet sufficient for a supply of 5½ million gallons per day for a population of three lakhs for about four rainless years.

The raw water is drawn from the reservoir through a part length of 30 inch and part length of 24 inch diameter pipes with a carrying capacity of 12 million gallons a day and led into the coagulation tanks. After treatment at these tanks and Jewell filters, pure water is pumped to Bangalore through a 24 inch diameter rising main.

The work, which cost nearly half a crore of rupees, was commenced in March 1930 and, on completion was opened by His Highness Sir Krishanajendra Wadiyar Bahadur, G.C.S.I., G.B.E., on 15th March 1933. After an instructive and most enjoyable trip the party returned to Bangalore in the evening.

MONDAY, JANUARY 6, 1936.

INSPECTIONAL TOUR; BANGALORE-MYSORE.

The delegates assembled outside the Council Hall at 9 A.M. for a three days tour to Mysore and other places, during which they were the guests of His Highness the Maharaja and on arrival at Mysore were accommodated in the neatly furnished cottages at the Race Camp.

During this tour, which was conducted under the leadership of Diwan Bahadur N. N. Ayyangar, Chief Engineer of Mysore, the party travelled mainly in buses, each bus being in-charge of a member of the Mysore P. W. D., who explained the various works enroute.

At Mandya, after lunch, the party went out to see the demonstration of the Automatic Syphon designed by Mr. V. Ganesh Iyer, at the Waste Weir of Mandya tank. The object of the syphon is to fluctuate the waterlevel in the tank thereby preventing breeding of mosquitoes. The principle on which it works is that the water gradually rises and spills over the lip of the funnel and into the cylinder; but the water is not allowed to go straight towards the centre, but is deflected by means of curved vanes fixed at equal intervals on the funnel; thereby the stream entering the funnel is delivered at its bottom in a direction slightly tangential; and the successive tangential flow from each compartment develops a circular motion in the water and finally forms a strong vortex before it enters the cylinder. With the formation of the vortex the confined air in the funnel is exhausted, and a vacuum developed rapidly. Immediately thereafter the syphon discharges full. The position of the rim of the cover decides the level up to which the water will be depleted and the syphon ceases to act when the water goes down below this lower rim.

The following is a brief description of the experimental and other road works inspected by the party during the day (January 6) :—

Bangalore to Mysore.

This section of the road connects the two large cities of Bangalore and Mysore and is of particular interest to Engineers, as it is subjected to heavy and fast moving traffic. The intensity of traffic can roughly be stated to be 150 mechanically driven vehicles and 300 animal drawn vehicles per 24 hours. These increase to 2½ times during the Birthday and Dasara occasions, each lasting for about 10 days. The average annual grant both under maintenance and special repairs is about Rs. 730 per mile. The surface of the road except for 2½ miles in the vicinity of Bangalore and Mysore is of water-bound macadam.

Just beyond Bangalore City limits, *i.e.*, from mile 4/4, a length of 2½ miles has been surface-painted with spramex three years ago. The width is five yards and the cost works to Rs. 3,200 per mile for the first coat.

The following experimental works, excepting items 5 to 7 and 9 to 12 have been done between the 7th and 15th miles, from a grant out of the Reserve with the Government of India.

1. Shalimar tar painting for one mile length of 5 yards width from mile 2/7 to mile 1/8. Cost per mile Rs. 4,550.

DETAILS OF WORK AND SPECIFICATIONS.

Surface Cleaning.—The road surface should be examined for ruts and pits and, if existing, they should first of all be painted with tar and filled with jelly and well tamped. The road surface should be thoroughly cleaned of all loose dust and particles by wire and bristle brushes. The finer particles should be dusted off by fanning with gunny bags. The surface to be tarred should be perfectly dry.

Application of Tar.—This is applied in two coats, the tar No. 1 being used for the first coat and the tar No. 2 for the second coat to be laid within three months after the first coat is laid. Except that hard and graded stone chips are required for this work, the application of this tar is akin to that of asphaltic products like Spramex, etc. The tar No. 1 is first heated to 240° F., and applied to the cleaned road surface at the rate of ¼ gallon per square yard. It is immediately blinded with hard stone chips at the rate of 3 cubic feet per 100 square feet, and consisting of ¾ inch to ½ inch 60 per cent. and ½ inch to ⅛ inch 40 per cent. The chips are then rolled into the road by a Steam Road Roller.

For second coat surface painting, the tar No. 2 is applied at the rate of ⅛ gallon per square yard, and blinded with stone chips at the rate of 2 cubic feet per 100 square feet and consisting of ½ inch to ¼ inch 60 per cent. and 3/16 to ⅛ inch 40 per cent. The tar No. 2 is applied at a temperature of 250° F. The chippings are finally rolled by a Steam Road Roller. In either case, the tar is easily heated in open drums and applied to the road surface by means of pouring pots or buckets and spread evenly by brushes fitted with a long handle.

The work was entrusted to Messrs. General Construction Co., Ltd., Madras, and the following is the data of cost per mile of Shalimar tar painting (2 coats) as done on the Bangalore-Mysore Road.

Data per mile; Company's work; 5 Yards width—

	Rs.
1. Cost of tar and labour charges for both coats . . . (at Rs. 4-14-0 per 100 square feet as per Company's quotation)	3,861

Departmental Work—

1. Quarry chips as per Company's specification at 5 cubic feet per 100 square feet. 160 cubic yards at Rs. 3-8-0 per cubic yard	560
2. Rolling charges at Rs. 50 per mile for each coat . . .	100
3. Sundries such as barricading, etc. (lump sum) . . .	29
Total cost of Shalimar tar painting (2 coats) per mile 5 yards wide	4,550

2. Shell macadam trackways 3 inches thick with Spramex on top for 5 yards width, for one furlong in mile 2/8. Cost per mile Rs. 8,200.

Details of work and specifications.

Excavation of trenches.—After correctly marking the position of the tracks symmetrically on either side of the centre of the metalled roadway, the trenches should be excavated to the width and depth decided, generally 2 feet and 3 inches respectively. The gauge between the tracks should be 4 feet 8-inches centre to centre. The sides and bottom of trenches should be trimmed up as neatly as possible by means of hand tampers.

Shelmac mixture.—The materials required for this are Mexphalte and Shelmac and stone jelly of 1½ inches to 2 inches size. These are to be mixed in the requisite proportion in the Mixing Plant. The Mexphalte and Shelmac are first to be mixed hot in the proportion of 2 to 1 and then the cold aggregate is to be added at the rate of 4 cubic feet for 13 pounds of the mixture. Care should be taken that each individual stone is well coated with asphalt.

Depositing of the Shell Macadam.—This mixture of the Shell Macadam, as it is called, should then be carried in a wheel barrow on to the site and deposited in the excavated and formed trenches to the required depth, the surface of the trenches being previously cleaned and dabbed with the asphalt mixture at the rate of one gallon per 100 square feet. After being hand-packed, the Shell Macadam should be well rolled so that the surface of the tracks becomes flush with the adjoining surface.

Sealing Coat.—A sealing coat with Mexphalte and ½ inch to ⅜ inch stone chips should then be given over the Shell Macadam surface and rolled again. The sides and centre of the tracks should then be formed and rolled to the proper camber.

The following is the data of cost per furlong of these tracks as laid—

		Rs.	A.	P.
1.	Labour charges for excavating trenches, forming them and depositing Shell Macadam complete, as per nominal roll	104	0	0
2.	Shelmac 3 barrels	97	11	0
3.	Mexphalte 9 drums	160	0	0
4.	Stone jelly 1½-inch to 2-inch size 40 cubic yards at Rs. 2-13-0 per cubic yard	112	8	0
5.	Stone chips ⅛-inch to 3/8-inch, 10 cubic yards at Rs. 3-8-0 per cubic yard	35	0	0
6.	Gunny bags	3	2	0
7.	Wire Brushes, etc.	22	0	0
8.	Coal for heating asphalt 1 ton	23	0	0
9.	Fuel ¾ ton	8	0	0
10.	Mobil oil, grease, etc., for Diesel Roller	16	15	0
11.	Hire charges on mixing plant	20	0	0
12.	Rolling charges	10	0	0
13.	Sundries, such as barricading, watchman, etc.	7	12	0
	TOTAL	620	0	0

	Rs.
Cost per mile 8 × 620	4,960
Add for Spramexing on top for 5 yards width	3,200

Therefore total cost of Shell Macadam tracks with Spramex painting on top for 15 feet width per mile Rs. 8,160 or say Rs. 8,200.

3. Shell sheet 2 inches rolled down to 1½ inches thick, 12 feet wide for one furlong in mile 3/8. Cost per mile Rs. 9,120.

DETAILS OF WORK AND SPECIFICATIONS.

Preparation of surface.—The road surface selected should be generally good being free from depressions and high spots. If found, they should be first levelled and the surface thoroughly cleaned by wire and bristle brushes, dusting off with gunny bags. The cleaned surface is then to be dabbed with heated asphalt at the rate of 1 gallon per 100 square feet, before laying the pre-mix. It is also necessary to provide some lateral support to the pre-mix during and after laying and this can be easily done by retaining a permanent water-bound macadam of 3 feet width on either side and then keying on the pre-mix into these by cutting a trench 4 inches × 3 inches, the surface of the water-bound macadam surface (*i.e.*, 3 feet width at sides) being spramexed.

Shell Sheet Pre-mix.—The materials required for this are Mexphalte, Shelmac, graded jelly from ¾-inch to 1-inch size and clean medium-grained sand. These are all to be mixed in the special mixing plant in requisite proportions. The Mexphalte is first to be heated to 350° F. and to this Shelmac at atmospheric temperature should be added in the proportion of 2 of the former (*i.e.*, Mexphalte) to one of the latter (*i.e.*, Shelmac). To this mixture is to be added the graded jelly of ¾-inch to 1-inch size at the rate of 3 cubic feet for 10 pounds of the mixture. After the jelly is thoroughly coated with the asphalt, sand is to be added and the requisite quantity of asphalt put again. The sand is intended to fill the voids in the aggregate and give a denser mixture. Due precautions should be taken to see that the jelly and sand are perfectly dry before they are mixed with asphalt.

Laying of Shell Sheet Pre-mix.—This mixture of asphalt, jelly and sand is dropped from the Mixing Plant into a wheel barrow and taken to the site and deposited to a uniform depth of 2 inches for 12 feet width by means of rakes and powrahs. It is then consolidated to 1½ inches depth by a steam road roller and the road opened to traffic after 24 hours. No seal coat is required here as the sand used in the mix will work out to the surface by the traffic and form a seal coat itself.

The following is the data of cost per furlong of the above works as laid on the Bangalore-Mysore Road.

Shell Sheet 12 feet wide and 12 inches thick.

	Rs.	A.	P.
1. Labour charges for cleaning road and laying the pre-mix, etc., complete as per nominal roll	98	14	0
2. Mexphalte 15 drums	265	15	0
3. Shelmac 7 barrels	228	0	0
4. Graded jelly ¾-inch to 1-inch size 45 2/3 cubic yards at Rs. 4 per cubic yard	182	0	0
5. Sand 22½ cubic yards	5	10	0
6. Mobil oil, gear oil, grease, etc., required for the roller	40	11	0
7. Gunny bags 40	6	4	0
8. Coal for heating asphalt 1¼ tons	29	0	0
9. Fuel 1 ton	12	0	0
10. Brooms	0	4	0
11. Other sundry charges, such as barricading, watchman, etc.	27	6	0
12. Hire charges for plant	50	0	0
13. Rolling charges	10	0	0
14. Forming sides with new jelly	184	0	0
TOTAL	1,140	0	0

Therefore cost of laying shell sheet (1½-inches) for 12 feet width per mile Rs. 1,140×8=Rs. 9,120.

4. Granite slab tracks 4 to 6 inches thick and slabs 6 to 9 feet in length, with one line dressing with spramexing on top for 5 yards width for one mile length from miles 4/8 to 7/8 and 8/9 to 3/10. Cost per mile Rs. 13,760.

DETAILS OF WORK AND SPECIFICATIONS.

Slabs.—Slabs should be of granite of approved quality, hard, even, sound, durable and of fairly uniform thickness between 4 inches to 6 inches and with lengths varying from 6 feet to 9 feet. The width of slabs should be 2 feet when dressed to square. The surface at top should be one line chisel dressed.

Excavation of trenches.—After correctly marking the position of trackways symmetrically on either side of the centre line of the metalled roadway, the trenches are to be cut to a sufficient width and depth just enough for laying in the slabs. The gauge between the slab tracks is to be 4 feet 8 inches centre to centre.

Laying of slabs.—The slabs should be carefully placed in alignment and firmly bedded on the foundation with the surface flush with the adjoining metalled surface. Any unevenness below the slabs should be made up by packing well with gravel and the excavated jelly. The tracks are to be level with the camber of the road in straight portions and with the required super-elevation suitable to a speed of about 30 miles per hour being given on curves.

Slabs should be laid with the joints not exceeding ½ inch in thickness and vertical joints should be dressed to square. The joints are to be well packed with gravel.

Consolidation of sides and centre of tracks.—The adjoining sides and portion between the tracks should be properly formed and consolidated with fresh metal of ¾-inch to 1-inch size so as to ensure a uniform surface of the road along the longitudinal edges of the slabs.

The following is the data of cost per mile of the slab tracks as laid on the Bangalore-Mysore Road. Data per running yard.

	Rs.	A.	P.
1. Excavation of trenches. 3 feet × 2¼ feet × 5/12 feet= 2 2/3 cubic feet at Re. 0-4-0 per cubic yard	0	0	5
2. Cost of slabs including 1 line dressing, laying etc., complete. 3×2 feet=6 square feet at Re. 0-6-6 per square foot	2	7	0
3. Consolidation of sides including cost of 4 cubic feet metal, at Rs. 3-8-0 per cubic yard	0	8	4
TOTAL	2	15	9
or say Rs. 3 per running yard.			
Therefore the cost per mile 8×220×2×3	10,560	0	0
Add for spramexing on top for 15 feet width	3,200	0	0
Therefore total cost of slab tracks with spramex painting on top for 15 feet width per mile	13,760	0	0

5. Painting with spramex for 5 yards width, one furlong in length in mile 8/8. This is the asphaltic product manufactured by the Burmah-Shell Company and its application is common. Cost per mile Rs. 3,200.

6. Painting with emulsion prepared at the Government Soap Factory, Bangalore, for 5 yards width from mile 1/9 to 5/9. Cost per mile Rs. 2,120.

Specification for 1st coat work.—The surface of the road selected should be restored to the original cross section and proper drainage provided. The ruts or any pot holes should first be cleaned and after painting with emulsion, should be filled with jelly and well tamped. If the road is badly worn out, it should be re-coated with fresh metal and after allowing traffic for about 2½ months, the surfacing work should be taken on hand. The road surface must then be cleaned thoroughly, care being taken not to loosen and dislodge the metal. A gang with wire brushes should first remove the caked mud and these are followed by a gang with bristle brushes or cocoanut brooms and who in turn is followed by a gang with gunny bags who sweep away the remaining dust. It is absolutely imperative that the road should be properly cleaned if good results are to be obtained.

Before applying the emulsion over the cleaned surface, it is advisable to damp the road slightly with water as this helps the emulsion to penetrate the road surface to some extent and also to lay the dust and give a clean surface. The emulsion is applied by means of pouring pots fitted with baffle mouth pieces or in buckets and spread by brushes fitted with a long handle. The surface is treated by pouring in longitudinal strips, working from the centre of the road outwards. An even distribution of the emulsion over the road surface is what is to be aimed at. This has to be done carefully by an even movement in one direction only and no pushing to and fro.

When the emulsion is first put on the road it is brown in colour but after half an hour in winter season and 15 minutes in summer, depending upon the temperature, it gradually becomes black indicating the break of the emulsion and the separation of the water and asphalt; just when it becomes black, the blinding material should be spread on the road. For single coat work, the quantity of emulsion required is 1 gallon for 2½ to 4 square yards, depending on the texture of the road surface, a rough surface taking more emulsion than a smooth one. Similarly, the nature and amount of chippings required depends on the texture but usually ½ inch chippings are most suitable and they should be spread at the rate of 3 to 4 cubic feet per 100 square feet. If the surface treated is very smooth or is an old surface dressed road, it is advisable to use 1 gallon of emulsion per 5 to 6 square yards, and blind with ¼ inch to ⅜ inch chippings.

After the blinding material has been spread on the road, it should be rolled thoroughly and if any emulsion appears to come to the surface it is advisable to spread more chippings. After rolling, the road may be opened to traffic.

The following is the data of cost per furlong for surfacing with the new emulsion as done on the Bangalore-Mysore Road.

	Rs.	A.	P.
1. Emulsion 375 gallons at Re. 0-6-6 per gallon	152	10	0
2. Transporting emulsion from factory to site of work	8	0	0
3. Chippings ½ inch size 15 cubic yards at Rs. 3-8-0 per cubic yard	52	8	0
4. Cleaning road, spreading emulsion and chippings as per nominal roll	22	8	0
5. Rolling charges for one day at Rs. 10	10	0	0
6. Tools and Plant such as wire and bristle brushes, baskets, etc. (lump sum)	9	0	0
7. Sundry items such as barricading, etc. (lump sum)	10	0	0
TOTAL	264	10	0
	or say Rs. 265		

Therefore cost of painting with spramex, emulsion per mile.

5 yards wide $= 8 \times 265 =$ Rs. 2,120

N. B.—The data will differ for moffussil stations as railway freight on emulsion will have to be taken into account in this case.

7. Soap Factory emulsion pre-mixed surface 3 inches, rolled down to $2\frac{1}{2}$ inches thick, 5 yards width, one furlong in length in mile 6/9. Under progress.

8. Bonded cement concrete 3—2—3 section re-inforced with rabbit netting, 5 yards width, one furlong in length in mile 7/9. Cost per mile 18,100.

DETAILS OF WORK AND SPECIFICATIONS.

Preparation of the base.—The old water-bound macadam surface should be cleaned thoroughly by wire and bristle brushes so as to have the metal protruding. Any deep ruts or pot holes should be filled and consolidated with good material before concrete is laid. To strengthen and secure the edges and ensure that the concrete is flush with the rest of the road, the sides of the metalled portion should be trimmed 3 inches deep and 18 inches wide along the edges.

Forms must be laid to the correct line and grade on each side of the road. This should consist of curbs of one line of wire-cut-brick, laid flat with 1:8 cement mortar No tamping and screeding will be allowed on the forms for 24 hours after they are constructed.

Placing re-inforcement in position.—The re-inforcement which may consist of wire netting 2-inches square mesh No. 16 gauge or rabbit netting 2-inches bee-hive mesh No. 16 gauge, shall be placed over the cleaned surface and fixed in position with iron nails so as to be approximately in the centre of the 2-inches concrete surfacing. The re-inforcement should be lapped at least 4 inches at every joint and secured with wire ties.

Depositing concrete.—After laying the re-inforcement and before depositng concrete, a neat cement grout of the consistency of thick cream should be spread with brushes evenly over the surface of the road to secure a good bond to the existing metal. The concrete should consist of 1 part of good portland cement to 3 parts of hard clean and evenly graded sand and 4 parts of clean, hard, coarse aggregate with the size varying from $\frac{3}{4}$-inch to $\frac{1}{4}$-inch. This should be deposited to an approximate thickness of 2 inches. The cement grout should only be about 2 feet in advance of the deposition of the concrete as otherwise it will dry out and be ineffective.

Screeding and tamping.—After the concrete is deposited, it shall be brought to the proper camber by means of a wooden screed or tamper fitted with handles on either ends and weighing not less than 5 pounds per inch foot and not less than $2\frac{1}{2}$ inches wide. Immediately after screeding or tamping is completed and before the concrete hardens, the surface shall be examined for high or low spots and any needed correction made by adding or removing concrete. After the screed tamper has left the surface approximately true, the concrete should be allowed to remain for about 20 minutes and as soon as the water sheen has disappeared, a wooden float must be worked lightly over the surface with a circular motion by a man or a bridge. This bridge may consist of a plank supported clear of the road.

Transverse joints.—At every 33 or 36 feet intervals, these transverse joints shall be left with the width not exceeding $\frac{3}{8}$ inch and then filled with poured bitumen.

Curing.—As soon as the surface of the concrete has attained sufficient hardness after the final finishing operations, it shall be covered with empty cement bags and kept moist until the concrete has taken the final set. Thereafter, the surface should be flooded with sufficient water continuously for 10 days after the concrete is laid by means of ponds built over the slab.

The following is the data of cost of the above work, per furlong 5 yards, wide and 3-inches—2-inches—3-inches section as carried out.

Data per furlong 5 years width 3-inches—1-inches—3-inches section.

A. MATERIALS—

	Rs.	A.	P.
1 Portland Cement (Nilgiri brand) 20¼ tons at Rs. 47-8-0 per ton	961	14	0
2. Aggregate 65 cubic yards at Rs. 3-8-0 per cubic yard . .	227	8	0
3. Sand. 48 cubic yards at Re. 0-8-0 per cubic yard . . .	24	0	0
4 Wire-cut-bricks for lining 1,800 at Rs. 30 per 1,000 . . .	56	0	0
5. Re-inforcement, *i.e.*, 2 inches wire netting No. 16 B.W.G. .	377	14	0
B. LABOUR :			
1. Cleaning road, fixing re-inforcement in position, mixing and laying concrete including tamping, curing, etc., as per actuals	300	0	0
C. TOOLS AND PLANT : *i.e.*, tampers, bridge, measuring boxes, floats, bulkhead, including wire brushes, etc.	130	0	0
D. 1. MISCELLANEOUS ITEMS : forming sides with new jelly, barricading, watchman, etc. (lump sum)	90	0	0
2. Forming diversion road	60	0	0
3. Providing expansion joints at every 33 feet intervals with bitumen filling (lump sum)	5	0	0
4. Sundry charges like wire nails, wire ties, etc. . . .	37	12	0
Total per furlong Rs. .	2,260	0	0

3—2—3 inches section per mile=8×2,260=Rs. 18,080

Therefore cost of laying re-inforced concrete road 5 yards width,
or say Rs. 18,100.

9. Painting with Texaco emulsion prepared by the Civil and Military Station Municipality, Bangalore, for 5 yards width and half mile in length from mile 4/10 to miles 7/10. (The specification and data of cost are the same as described for spramex emulsion painting between mile 8/8 to mile 8/9.)

10. Painting with Bhadravati tar for 5 yards width with a thin coat of Soap Factory emulsion over it from mile 8/10 to mile 3/11.

11. Surface painting with molasses for 5 yards width from mile 4/11 to mile 8/13 and 16th to 44th mile. Cost per mile Rs. 90

DETAILS OF WORK AND SPECIFICATIONS.

Preparation of surface.—The old surface is swept of all loose dust by cocoanut fibre brooms so as to expose the interstices of the metal to about 1/16-inch to 1/8-inch depth, care being taken not to dislodge the consolidated metal.

Application of Molasses.—The molasses is mixed with water in the proportion of about 1 :1 and applied over the cleaned surface either by means of pouring pots or buckets or by a water lorry fitted with spraying attachment. The quantity of molasses required per mile 5 yards wide is about 10 tons. After it is spread out evenly over the surface the molasses is allowed to soak for half an hour. Then coarse sand available in the *nalas* nearby is spread over the molasses while it is still in a slightly wet condition and the traffic is allowed to pass on the surface immediately. After about a fortnight, the sand and molasses are worked thoroughly into the interstices by the traffic and the surface looks dark somewhat like a tarred or asphalted surface.

The following is the data of cost per mile 5 yards width of surfacing with molasses as done on the Bangalore-Mysore Road :—

	Rs.	A.	P.
1. Molasses 10 tons at Rs. 2 per ton (concession rate) . . .	20	0	0
2. Cleaning road and applying molasses	32	0	0
3. Sanding 24 cubic yards at Re 0-7-0 per cubic yard . . .	10	8	0
4. Railway freight at concession rates and carting and other charges (lump sum)	25	0	0
5. Cost of other materials required such as tools and plant, etc. .	2	0	0
Total cost per mile 5 yards wide .	89	8	0
or say Rs.	90	0	0

12. Consolidated granite metal grouted with molasses and lime for 4 yards width from mile 1/14 to mile 8/15. Cost per mile Rs. 350.

DETAILS OF WORK AND SPECIFICATIONS.

The furlong selected is picked and formed with the new metal and rolled by a Steam Road Roller using only a small quantity of water after spreading the metal. About 8 drums of molasses mixed with about half its quantity of water by volume and 3 candies or ¾ ton of slaked lime by weight, is then put over the rolled metal and allowed to soak into the interstices. The combination of molasses and lime results in the formation of Tri-Calcium-Sucrate which is insoluble in water. A thin coating of gravel is then given over this surface. Again, about one drum of molasses mixed with thrice or even four times is quantity of water by volume is put over the gravel. By this means, the molasses and gravel are further forced into the interstices in the metal. Finally a thin blinding of sand is given and the surface rolled again. The molasses thus works its way through the metal and binds the individual stones together and forms itself into a hard and compact mass. The quantity of molasses required per mile 4 yards wide is about 24 tons.

The following is the data of cost per mile 4 yards width of grouting the metal with molasses, as worked out on the Bangalore-Mysore Road :—

	Rs.	A.	P.
1 Molasses 24 tons at Rs. 2 per ton (concession rate)	48	0	0
2. Railway freight at concession rate and cartage to site, etc. .	55	0	0
3. 24 candies of lime at Rs. 7 per candy	168	0	0
4. Mixing and spreading molasses	50	0	0
5. Barricading, lighting and other sundry charges . . .	29	0	0
Total cost of grouting per mile 4 yards width Rs.	350	0	0

N.B.—Cost of metal, gravel, sand and consolidation charges are not taken into account.

In all the above cases the original surface was re-consolidated with granite metal 1½ inches thick. Samples of this metal were sent to the Alipore Test House, and the statement giving their test results is reproduced below :—

Nomenclature of stone.	Particulars of quarry.	Percentage loss of weight in a Deval type attrition tester.		French coefficient of wear 40. Percentage loss of weight.		Specific gravity.	Notes on Petrological examination by the Geological Survey of India.	Remarks.
		Dry test on 11 lbs. of stone.	Wet test on 11 lbs. of stone with 1·1 gallon of water.	Dry test.	Wet test.			
Fine-grained biotite granite.	Road side quarry near the 8th mile of Bangalore Mysore Road.	1·8	4·1	22·2	9·8	2·71	Fine grained biotite granite, unsuitable for use as road metal would wear rapidly, as it is liable to break up and decompose under conditions prevailing in an untarred macadamized road, and lacks binding properties.	The wearing qualities of the stone, as received, will be good during the dry weather and fairly good during the rains. It is, however liable to break up and, decompose and lacks binding properties.
Hornblende-Schist.	Ditto .	2·0	12·0	20·0	3·2	2·89	Hornblende-Schist, unsuitable for use as road metal; would not stand up to the wear of traffic.	The wearing qualities of the stone will be good during the dry weather, but bad during the rains. Hence it will not stand up to the wear of traffic.

(A demonstration of "Molassing" the surface and molass grouting was shown to the delegates in the 14th mile.)

These experimental lengths are in continuous strips so that the relative durability and economic value of each under similar traffic conditions can be judged As these works have been done only lately, we have to wait for results for some time.

Though a small portion of the molasses gets spread out during the rains, still there is a good deal left on the surface and, after the rains, renewal by a thinner solution would restore the surface to the required condition. The entire length of road from the 15th to 44th mile has been "molassed".

The metal used on this section of the road is mostly granite of a fairly hard variety. About six miles, from the 31st to 36th mile (both inclusive) are metalled with a kind of reddish metal containing more of pinkish felspar of large size available only in this portion. The peculiar characteristic of this variety of metal is that it is light and gives a smooth and uniformly wearing surface, besides giving a pleasing dull red appearance to the road. Though the felspar content is more and the metal is light and soft due to the partial weathering of felspar, yet the surface once re-coated with this metal is found to last well from two to three years. It is recommended that wherever this kind of red metal is available, it may be used with very good results in preference to field metal.

If examination and tests of this metal are carried out in the usual way, metal would be condemned as unfit for use. But the practical experience has been, that it makes a more satisfactory surface than the harder varieties of metal.

At Mandya, about 60 miles from Bangalore, a sugar factory has lately been started, due to which the lorry and cart traffic carryimg cane to the factory is extremely heavy. The crushing strength of the factory is as much as 1,200 tons of sugar-cane per day and a major portion of this traffic passes on this road. From the 45th mile on this road, the surface has been improved much of late by the widening of the embankments, the lowering of berms, improvement of curves and the opening of diversions. These deviations of the road which was formerly passing through busy towns have been of immense comfort to motorists and a great relief to the towns-people.

Over a long length of this road, the surface has been "molassed". It has been found to be a satisfactory method of preserving the surface from breaking during the hot weather.

SLAB TRACKS ON A GRAVEL ROAD.

In the deviation at Maddur in mile 7/49, trackways of granite slabs 2 feet in width and 4 feet 8 inches centres have been laid. The slabs at the joints are supported on bearing slabs of 2 feet×1 foot to prevent unequal settlement. The introduction of bearing slabs has its own inconvenience and experience will show if this is desirable The cost of laying these slab tracks worked to Rs. 8,000 per mile.

TRACKWAYS AT MANDYA.

At a distance of 2½ miles to the north of Mandya town, sample macadam trackways on a gravel road which has to carry lorries and bullock carts heavily loaded with sugar-cane have been laid.

The construction of the trackways is briefly as below :—

Longitudinal trenches on the road, 2½ feet wide, 12 inches deep, 4 feet 6 inches apart centre to centre are excavated, filled in to a depth of about 5 inches with unbroken 4 to 6 inches size jelly and hand-packed. A layer of gravel 1 inch thick is put on, watered and hand-tamped. Over this, unbroken 1 to 2 inches size jelly (broken stones) to a depth of 2 inches is placed, watered and tamped. A second layer of gravel 1 inch thick is spread thereon and as before watered and consolidated. Over this the final layer of broken metal ¾ inch to 1 inch size is spread to a depth of 2 to 3 inches, watered and rolled and the surface to a width of 7 feet finished with gravel and sand. The cross slope adopted for the surface of the road is 1 in 30.

The delegates were shown the several stages involved in the sample macadam tracks specially made for a length of 210 feet.

Similar tracks have been laid on the road on which the delegates passed before they reached the site of the demonstration tracks. These were laid a year ago and have since been subjected to heavy traffic of carts and lorries. They have been standing satisfactorily; in places where the sub-soil is soft and the track has subsided, additional field metal is put on, rolled and the surface brought up to level.

The traffic census on the road is as below :—

Carts loaded with $1\frac{1}{2}$ ton of cane per day	100
Unloaded carts	100
Loaded lorries 6 tons	32

Average load per $2\frac{1}{2}$ feet width of track per day is 200 tons during a period of 8 months in the year.

The tracks are very serviceable especially in irrigation tracts which have moist sub-soils.

5. The Bangalore-Nilgiri Road.

This road commences from mile 3/80 of the Madras-Cannanore road and runs *via* Seringapatam and Mysore. The mileage allotment up to and beyond Mysore is Rs. 800. The Mysore Municipality maintain the road from mile 3/85 to mile 8/90. From mile 3/80 up to Mysore is mostly in wet lands and the sub-soil is always moist and yielding. Quartz and inferior quality of quartz are the only available types of metal in this section.

Asphalt grouting has been done from mile 3/85 to mile 6/86 and part of mile 7/85 at a cost of Rs. 17,000 including the cost of metalling and bituminous surface painting has been done from mile 5/84 to mile 2/85 at a cost of Rs. 9,000. Spramexing has been done from mile 3/83 to mile 6/84 at a cost of Rs. 14,000.

The party arrived at the Race-View Camp, Mysore, late in the evening and proceeded to the Palace to write their names in H. H. the Maharaja's visitors' Book, after which they were taken to the Chammundi Hills to see the Palace illuminations specially arranged for the occasion, which was a most enchanting and beautiful sight.

Inspections and visits at Mysore.

TUESDAY, JANUARY 7, 1936.

In the morning the party visited the Palace, Sandal Oil Factory, Silk Factory, Technical Institute and Zoological Gardens. After lunch the party were taken to see places of interest at Seringapatam and to visit the famous tunnel, at Hulikere, some 9,200 feet in length, over the Irwin canal and thereafter to the world famous Krishanraj Sagar Dam across the Cauvery River where tea was provided on a very lavish scale amidst enchanting surroundings. The reservoir is the second largest in India, the masonry dam being $1\frac{3}{4}$ miles in length and 130 feet in height. It took no less than ten years to complete its construction.

A large area at this rear of this magnificent dam is laid out in Terrace Gardens called "Brindavan", where fascinating fountains and cascades cleverly illuminated with coloured lights and search lights, after dark, present a scene of enchantment and beauty.

Inspectional Tours ; Mysore-Bangalore.

WEDNESDAY, JANUARY 8, 1936.

The party left for Bangalore on the morning of the 8th of January, 1936, inspecting the following roads on the way :—

(1) The Seringapatam Sosale-Sivasamudram Road.

It starts from the 76th mile of the Madras-Cannanore road and is 42 miles long and connects Seringapatam of historic fame, Somanathpur of archæological fame and the important power-generating station of Sivasamudram.

In the 28th and 29th miles, macadam trackways have been done. The road runs here in black cotton soil and it was impassable for motors during the rainy season. The tracks laid a year ago have been standing satisfactorily.

(2) The Mysore-Talkad-Sivasamudram Road.

This road is 17 miles long. After the construction of the two bridges across the Cauvery and the Kabini, it has become important, as it connects Sivasamudram and Kollegal on the side of Sivasamudram and T. Narasipur and Chamarajnagar on another

side and leads to Satyamangalam and Coimbatore after crossing the Kabini. Quartz and lime-stone metal are used for the surface. The life of a re-coat is not more than 2 to 5 years.

Near T. Narsipur a halt was made to inspect the Vane Vilas Bridge across the Kabini river and Krishnarajendra bridge across the Cauvery river.

A visit was also paid to the famous Somnathpur temple which is a gem of medieval Indian art and a splendid example of what is known as the Hoysula style of architecture.

The party next visited the great Hydro-Electric generating station on the Cauvery river at Sivasamudram which provides electricity to the whole of Mysore State including the Kolar Gold fields and Bangalore. Lunch was arranged at the local club house. Bangalore was reached in the evening.

Visits and Functions at Bangalore.

THURSDAY, JANUARY 9, 1936.

In the evening after their day's session in the Sir Puttana Chetty Town Hall, the delegates visited the Indian Institute of Science, Bangalore. The work being done here is of great scientific interest and the more erudite of the party keenly watched the demonstration of some of the most delicate instruments in the laboratories.

FRIDAY, JANUARY 10, 1936.

In the morning, the delegates saw in detail the working at Bangalore Porcelain Factory which supplies the total requirements of insulatory of the great electrical distribution system of the State and produces other articles such as two-or three-way cleats, crockery, images, porous pots, etc.

The Second Indian Roads Congress Dinner.

The second Indian Roads Congress Dinner was held at the West End Hotel, Bangalore, on the night of the 10th January, 1936. Covers were laid for some seventy members of the Congress and eighteen distinguished guests the principal of whom were Amin-ul-Mulk Sir Mirza M. Ismail, Kt., C.I.E., O.B.E., Dewan of Mysore and the Hon'ble Mr. L. G. L. Evans, C.I.E., I.C.S., Resident in Mysore.

At the end of the dinner, Rai Bahadur Chhuttan Lal, President of the Congress, in proposing the toasts of His Highness the Maharaja of Mysore and the Guests delivered the following speech :—

Sir Mirza Ismail, Mr. Evans and Gentlemen; On behalf of the delegates attending the Indian Roads Congress, it is my most pleasant duty to thank you Sir Mirza Ismail and through you, the Government of His Highness the Maharaja of Mysore, for the kind invitation to hold the Congress here in Bangalore and to visit not only works, which concern a Road Engineer, but also other noted works of engineering and general interest. In opening the Congress yesterday you were pleased to remark that by holding the Congress at Bangalore, an honour has been conferred on the State. You will, I hope, pardon me, Sir, if I beg to differ from you, for we all feel that the invitation to hold the Congress here and to be His Highness' guests during our tours has been a great honour to us all. I may, therefore, be permitted to say that the honour is ours, and not yours, and our grateful thanks are due to His Highness for the hospitality extended to us.

During our tours in Bangalore and Mysore, we were deeply impressed by the manifold activities of the State in matters industrial and economic. Irrigation for agricultural purposes, water supply for development of power and human consumption, and communications have been tackled in a most comprehensive manner. The visit to Krishan Sagar with its fountains and cascades, lighted with all the colours of the rainbow, was suggestive of fairy land. In Bangalore we have been greatly struck by the improved roads with wide avenues. Palatial buildings on modern designs add greatly to the natural architectural beauty of this city. This, if you will permit me to say so, is very largely due to your initiative and to your keen interest in engineering. Sir, the State of Mysore owes a great deal to your foresight and wise statesmanship and it is a matter of congratulation that you have a band of workers who are carrying on the enlightened policy of His Highness in the various spheres of the administration in a manner which is the envy of others.

It is perhaps invidious to mention names but I cannot help saying that Diwan Bahadur N. N. Ayyanger and Mr. M. L. Narasimiengar have been unsparing in all their efforts to make our visit as comfortable and interesting as possible. We are all thankful to them and to all others for the pains they have taken in making arrangements for the Congress and for their courtesy to all of us, in various ways, and for providing us not only with refreshments but with the delicious tender cocoanut water flavoured with lime juice which, let me assure you, we have enjoyed to our heart's content. We shall carry the taste of this nectar of Southern India to other parts of India, where it is unknown. I believe, most of the delegates have examined the experiments with molasses with a very keen and observant eye and we hope greatly to benefit by them. Perhaps each one of us will carry with him the sweet scent of molasses to his home. But of this I will say a few words more. Molasses is said to attract black ants but as the road was remarkably free from them, some of the delegates perhaps doubted whether the material used on the road was really molasses. Another batch of delegates considered molasses as a commodity used by the poor labouring classes and did not envy Diwan Bahadur Ayyanger the Chief Engineer in keeping constant vigilance to prevent pilfering. Others again with scientific leanings, believed in its hygroscopic and adhesive properties, but were puzzled at the contradictory character of these two qualities. They argued that there can be no cohesion at the point of saturation with water. I personally have been deliberating in my mind whether to use it in preference to tar or not. Both are indigenous products and that consideration weighs a great deal with me but a serious objection has been raised for the first time against the use of tar in that it is said to impair the eyesight and effect the lungs. I have spoken to my friend, Col. Sopwith, about this but inspite of his earnest assurance to the contrary, I hesitate to brush aside the objection until sufficient time has elapsed to enable us to see its effect on the eyesight and lungs of persons advocating the use of tar on roads. At any rate the smell of molasses compares favourably with that of tar and for this reason, if not for any other, some may prefer to continue using the molasses.

It is not necessary on this occasion to dwell on the asthetic, professional or scientific character of the works visited by us but we have exchanged our ideas on matters affecting the construction and maintenance of roads, standardization of methods for recording road statistics and particulars of experimental work and installation of tracks and a research station or stations and have come to definite conclusions. This interchange of ideas and the pooling of experience has widened our outlook.

This is all I have to say, Gentlemen but before I resume my seat I must thank Mr. Mitchell and his Assistant Mr. Sondhi, for the efficient manner in which the Congress has been organized by them and for not sparing any effort in making it the success it has been. I am sure in saying so, I am voicing the view of all the delegates.

The Chief Guest, Amin-ul-Mulk Sir Mirza Ismail, Kt., C.I.E., O.B.E., Dewan of Mysore, in responding said :

Mr. President, Mr. Evans and Gentlemen: I thank you, Mr. Chhuttan Lal, very deeply for your kind references to myself. I need not tell you how greatly I appreciate this honour, and the pleasure of being here to-night.

I thank you most heartily for your graceful courtesy in toasting my Maharaja, and on behalf of His Highness I tender you his thanks for the many kind things that have been said about his State and about the hospitality that he has been able to extend to this great Congress. I can assure you that it is a matter of sincere pleasure to him to have so important a body holding in his State their first meeting after that at which the Congress was inaugurated. He is following your proceedings with the greatest interest since he is not only keen on everything that tends to the proper development of the State, but is also an ardent motorist himself and interested in the work of the Automobile Associations of both the West and the South of India.

I tender you sincere thanks also on behalf of the Government of Mysore for the kind things you have said of those who have been responsible for the maintenance of the roads in the past. If we have not been able to make your path as smooth for you as we could have wished, we have endeavoured to sweeten it by taking you to places endowed with beauty by nature or by art, and where there were none of these, with the products of industry in the shape of the molasses of Mysore. I hope you have all appreciated the sweet smelling surfaces that we have had prepared for you, but I hope also that none of your vehicles has shown the appreciation of them that my own car did last week when it skidded for joy on reaching one of them and attempted to thrust a bullock cart off it into the ditch.

As I said yesterday, we have nothing remarkably new in the shape of cures for bad surfaces to demonstrate. But I should like to add that, if any of you doctors wish for clinical material on which to make experiments, we have a great deal of that to offer.

So far I have spoken for what I may call the old brigade. There has, however, been born into the world within the last few days a new member of the family of Road Congresses in the shape of the Mysore Road Board, and while it has every appearance of being a lusty infant, with a Road Fund as young as itself to provide its nutriment, I feel that it is only right to ask your kindly interest in its future—to request you to be gentle with your little brother, to aid his first, tottering foot-steps, to chide him when he goes astray, and to encourage him with a birthday present of a grant whenever you feel he deserves it.

Having said so much by way of returning thanks for the compliments that have been paid to Mysore I now ask those who are not members of the Congress to drink to the health of that already extremely healthy body, coupling my toast with the name of Mr. K. G. Mitchell. I say it must be a healthy body because I understand that the Mysore Engineers have put the members of it through an extremely gruelling test, which they have all borne without turning a hair. The members of the great Engineering profession have a great pull over us others who simply sit and write, in that they have concrete records of their achievements which they can return to visit until their dying day, and which they can exhibit to their visitors. And I am afraid from what I have read of your programme that our Mysore Engineers have no exceptions to the rule. They have demonstrated to you many achievements of which I may say we, as well as they, are intensely proud. But the connection of most of them with roads seems to be just this, that you had to travel over most of the roads in the State to get to them.

I coupled this toast with the name of Mr. Mitchell, and I think you will all agree that he has shown himself the hardiest of them all. He has shown his confidence in the roads for which he is responsible by motoring 2,000 miles from Delhi to Mysore and I expect that he can now tell us with his eyes shut what part of India he is passing through from an automatic record in his own body of the number of bumps per mile. I expect he has also registered every degree of impatience and annoyance that is caused by the varying license regulations and toll-gate interruptions on his journey. It is proof of the sunny serenity of his temper that he has arrived quite unruffled by these annoyances, and after omitting not a single item of your strenuous programme, has been ready to take part in your discussions.

While Mr. Mitchell represents those of you who are members of the great profession of Engineers, I should like to couple with them the other delegates who represent the business side of road-making of whom the best known to us in Mysore is Mr. Ormerod. It was once said of certain Government functionaries that their purpose in life was to induce other departments of Government to 'distribute their neglect.' If I may borrow this phrase, Mr. Ormerod has made it his business during the last few years to induce Governments and other people concerned with the maintenance of roads to distribute their neglect, and to see that the undue share of it that was apt to fall to the roads went somewhere else. I am sure you will all agree with me that his persistence in making the lives of the neglectful ones a burden to them has been beyond praise. Nor have he or his associations been behind hand in constructive schemes of a most useful and practical nature. I can assure him that we shall heartily welcome him in Mysore whenever he is able to visit us with a view to the promotion of these schemes or, if he finds it necessary, with a view to awakening the Road Board to a sense of their duty.

Gentlemen, I give you the toast of the Indian Roads Congress :—May their shadows grow wider and their curves more generous as the years go on; may their roads be as broad, as smooth and as easy as the road that leads to destruction; may their way be ways of pleasantness and may all their paths be peace.

Messrs. K. G. Mitchell, C.I.E., and H. E. Ormerod, in nice little speeches, suitably replied to the eulogizing remarks, made about them by the Dewan of Mysore in his speech.

SUNDAY, JANUARY 12, 1936.

The delegates were taken around to see the principal buildings at Bangalore. They also visited, by invitation, the Palace and gardens of H. H. the Maharaja at Bangalore

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Kolar Gold Fields —Optional Tour.

MONDAY, JANUARY 13, 1936.

A party of some 20 delegates, left Bangalore at 8 A.M. on a visit to the Kolar Gold Fields, and in the way inspected the following roads :

(1) MADRAS-CANNANORE ROAD (KOLAR SIDE).

This section of the road forms an important and direct link between Bangalore and Kolar Gold Fields on the one side and Bangalore and Madras on the other. It is thus subjected to heavy traffic and being an important State Fund Road, the average annual cost of maintenance per mile of the road is Rs. 500 for the 1st 10 miles from 4th to 14th mile, Rs. 200 for 2 miles for the 15th and 16th mile and Rs. 300 onwards up to the Bangalore boundary.

The surface of the road is of water-bound macadam and the metal width is 4 yards throughout. Except for about 5 miles where laterite metal is used, the remaining length consists of granite metal. The former variety of metal, though soft in quality, is found to give a smooth and a more uniform wear of the road surface than the latter. But it is being gradually replaced by granite metal only.

(2) 29TH MILE UP TO KOLAR TOWN IN 42ND MILE.

KOLAR SECTION—The width of the road is 24 feet, of which 12 feet is metalled. The average expenditure per mile during the last 3 years is Rs. 395. Intensity of traffic is roughly 150 tons per day (per yard width).

(3) Cuddapah Railway Feeder Road.

The intensity of traffic increases from 150 to 300 tons per yard width on *Bazaar* days. The average outlay per mile works to Rs. 370.

(4) Kolar Gold Fields Road.

This is 10 miles in length. The intensity of traffic on this road is 400 tons per day. The average expenditure works to Rs. 570 per mile.

A demonstration of the premix work with spramex containing 60 per cent of bitumen was arranged for the delegates in the last mile.

Method of premix work adopted. The length treated is about 200 feet a day to a width of 18 feet. The surface is thoroughly cleaned with wire brushes and swept of all dust with coir brushes and gunny bags. All pits are filled with premixed metal The surface is wetted with water and a priming coat given at the rate of 3½ gallons of emulsion per square.

Metal is collected in measured heaps of 16 cubic feet which works out to 2 inch thickness per square. Including filling pits and levelling depressions, 21 cubic feet per square or an average thickness of 2½ inches is necessary. This is premixed with emulsion by manual labour at the rate of 6 gallons per square and then spread, hand-packed and rolled till it has fairly well set. Granite chips varying in size from 5/8 to 1/8 inch are spread on this at the rate of 6 cubic feet a square and the rolling continued for about 6 hours. After 2 or 3 days, a sealing coat is given as follows :—

The loose chips are brushed from the surface and a coat of emulsion is given at the rate of 4½ gallons per square. Then the chips which have been brushed aside are spread once again, supplemented by an additional 2 cubic feet per square and the whole surface is rolled for 4 hours. The cost works out to Rs. 11-12-0 per square of 100 square feet or Re. 1-1-0 per square yard. The details of cost are given below :—

	Rs.	A.	P.
1. *Materials* :—			
Granite metal 2½ inch thick per square 21 cubic feet @ 3-0-6, per cubic yard	2	5	9
Chips @ 8 cubic feet per square @ 0-2-0 per cubic feet	1	0	0
Emulsion :—			
(a) Prime coat per square 3½ gallons or 35 pounds per square.			
(b) Premix with metal 6 gallons or 3 pounds per cubic foot.			
(c) Seal coat 4½ gallons or 45 pounds per square.			
(d) Extra for overlap, filling pits, dryage, wastage, etc. 1 gallon. Total 15 gallons @ 0-7-6 per gallon.			
(0-6-6 per gallon @ Factory *plus* 0-1-0 conveying charges)	7	0	6
Total cost of materials per square	10	6	3

2. *Labour* :—

	Rs.	A.	P.	
12 Male coolies @ 0-6-0	4	8	0	
1 Head Cooly @ 0-7-0	0	7	0	
1 *Mistry* @ 0-12-0	0	12	0	
16 Women coolies @ 0-4-0	4	0	0	
1 Night Watchman @ 0-8-0	0	8	0	
Total	10	3	0	per day.
For 1½ days	15	5	0	

Surface treated including seal coat is 200 feet × 18 feet or 36 squares.

∴ Per square $\frac{15\text{-}5\text{-}0}{36}$ or Rs. 0-6-10.

3. *Engine charges* :—

For rolling with a ten ton Steam Road Roller, including seal coat. The rolling is done for 1½ days of 8 hours each day.

(a) Establishment.—

Driver, Rs. 30

Cleaner, Rs. 12

	Rs.	A.	P.
Rs. 42/- per month or for 1½ days . .	2	2	0
(b) Fuel, Oil, etc., for a day Rs. 11 or for 1½ days . .	16	8	0
(c) Hire charges for 1½ days	7	8	0
Total for 36 squares . .	26	2	0
Total per square .	0	12	0

On arrival at the Gold Fields the party was received by the members of the Mining Board and was divided into three batches. Each batch was placed under the charge of a responsible official of the Gold Fields, who showed them underground work in one or other of the mines at a depth of 7,600 feet or so.

On return from these lower regions, the party was entertained at lunch by the Board at the Kolar Gold Fields Club.

Lunch being over, Mr. Ormerod, in a suitable speech, thanked the members of the Mining Board for the kind hospitality extended to the delegates.

The party were then shown the workshops, surface works—including various processes employed for extraction of gold right upto the moulding of gold bricks.

The delegates returned to Bangalore in the evening and then dispersed

NOTICE.

PROPOSED REPRINT OF THE PROCEEDINGS OF THE INAUGURAL MEETING.

As a certain demand has been received for copies of the "Proceedings of the Inaugural Meeting of the Indian Roads Congress, 1934", which has long been out of stock, it is proposed to reprint the publication provided the total demand from members and others interested in roads amounts to 250 copies in which case the sale price is estimated to be Rs. 4 per copy.

2. The Proceedings of the Inaugural Meeting of the Congress which was held at New Delhi in December 1934 contains the first thirteen technical papers of the Congress covering, *inter alia*, the uses of Tar and Bitumen and Emulsions; Earth Road Development; Asphalt Roads; Cement and Cement Concrete Roads; and Test-Tracks; and together with the discussions run to 291 pages in print.

3. Applications for copies are being registered. Those interested are advised to book their orders with:—

The Secretary,
Indian Roads Congress,
C/o The Department of Industries and Labour,
Roads Branch, Simla.

INDIAN ROADS CONGRESS.

LIST OF PAPERS IN ANNUAL PROCEEDINGS.

Volume I—1934.

1. Objects and Organisation of a Permanent Indian Roads Congress by K. G. Mitchell.

1-A. Recent methods used for the treatment of roads with bitumen and tar in Delhi Province by A. W. H. Dean.

2. The trend of development in the United Provinces in the matter of improving road surfaces with special reference to recent experiment by C. F. Hunter.

3. Earth Road Construction and Maintenance by machinery by G. W. D. Breadon.

4. Earth Road Development and Stabilization with Gravel by Lieut. Colonel A. V. T. Wakely,

5-A. Progress made in the use of tar and bitumen in the Punjab since the last International Roads Congress in Washington in October 1930 by S. G. Stubbs.

5-B. Notes on the use of Tar, Bitumens and Emulsions in the Punjab by R. Trevor Jones.

6. Asphalt Roads by G. G. C. Adami.

7. The use of cement concrete for the construction of roads in the Bombay Presidency by L. E. Greening.

8. Cement Concrete Roads by W. J. Turnbull.

9. Concrete Roads in Hyderabad (Deccan) by M. A. Zeman.

10. Corrugation of water bound macadam road surfaces in the Bombay Presidency and a Cure by Henry J. M. Cousens.

11. Notes on the Plant used for Quarrying and Granulating and Operating Costs on the Gauhati Shillong Road, Khasi and Jaintia Hills Division, Assam, by B. F. Tayler.

12. Some Physical Aspects of Roads and Tyres by G. L. W. Moss.

13. Test Tracks—A suggestion by C. D. N. Meares.

Volume II—1936.

14. An Analysis of Delhi Road Traffic Census by R. L. Sondhi.
15. A study of the relationship between Vehicular Traffic and Road Surfaces as affecting the selection of an Economic Road Surface, by H. P. Sinha and A. M. Abbasi.
16. Traffic Census and Road Diagrams by Lt. Col. W. deH. Haig.
17. Economics of Road Maintenance by S. Bashiram.
18 Necessity for Surface Treatment of important tourist lines and some aspects of economical work in that direction by V. S. Srinivasaraghava Achariar Avl.
19. Treatment with Molasses of the Bangalore-Mysore Road by Diwan Bahadur N. N. Ayyangar.
20. The Road Problem in India with some suggestions by Col. G. E. Sopwith.
21. General Review of the Results of recent Road Experiments in India as revealed by modern practice by K. G. Mitchell.
22. Road Research and Results by C. D. N. Meares.
23-A. Roads in Rural Areas (Village Roads) by Hony. Capt. Rao Bahadur Choudhry Lal Chand.
23-B. Gravel Roads by Diwan Bahadur. N. N. Ayyangar.
23-C. Vitrified Bricks for surfacing Roads in Deltaic Districts by G. Gopala Acharya.
24. Oil as a binder for Earth and Gravel Roads by T. G. F. Hemsworth.
25. Cement Bound Roads by W. J. Turnbull.
26. The necessity for a reasonably Uniform Standard Loading for Design of Concrete Bridges and a suitable Loading for such and other types of Bridges on Highways in India by M. G. Banerjie.
27. Design of Highway Bridges—The necessity for an All-India Specification by W. A. Radice, G. Wilson and P. F. S. Warren.
28. Permissible Stresses in Concrete Bridge Design by W. J. Turnbull
29. Regulation and Control of Motor Transport in Mysore by H. Rangachar.
30. The Construction of the Shillong Jaintiapur Road in the Khasi Hills, Assam, by F. E. Cormack.
31. A Method of Rapid Road Reconnaissance by Captain W. G. Lang Anderson.

LIST OF MEMBERS OF THE INDIAN ROADS CONGRESS, AUGUST 1936.

Ordinary Members.

Mr. K. G. Mitchell, C.I.E., Consulting Engineer to the Government of India (Roads), New Delhi/Simla.

Mr. R. L. Sondhi, Assistant to the Consulting Engineer to the Government of India (Roads), New Delhi/Simla.

Mr. Guthlac Wilson, Engineer, Braithwaite Burn and Jessop Construction Company, Calcutta.

Mr. P. F. S. Warren, Director, Jessop & Co., Ltd., Calcutta.

Mr. W. A. Radice, Technical Adviser, Braithwaite Burn and Jessop Construction Co., Calcutta.

Mr. Alexander Jardine, Director, Jessop & Co., Ltd., Calcutta.

Mr. H. W. T. Hain, Managing Director, Braithwaite & Co. (India), Ltd., Calcutta.

Mr. Rathlin J. C. Tweed Work Manager, Braithwaite & Co. (India), Ltd., Calcutta.

Mr. B. N. Mookerjee, Principal Partner, Burn & Co., Calcutta.

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Mr. S. A. Roberts, Partner, Bird & Co., Calcutta.

Mr. N. V. Modak, City Engineer, Bombay Municipality.

Rai Sahib Hari Chand, Concrete Association of India, Lahore.

Mr. G. W. D. Breadon, District Engineer, Gurdaspur.

Mr. D. G. Sowani, Executive Engineer, Kolhapur State, Kolhapur.

Mr. M. C. Gupta, Municipal Engineer, Allahabad.

Mr. D. W. Goghari, State Engineer, Bhavnagar.

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Mr. D. E. Gough. Representative of the Society of Motor Manufacturers and Traders, Ltd., Ballard Estate, Bombay.

Mr. E. A. Nadirshah, Deputy Chief Engineer, Bombay Municipality.

Dr. M. A. Korni, Chief Engineer, Reinforced Concrete Department of Bird & Co., Ltd., Calcutta.

Mr. H. M. Surati, Divisional Engineer, Roads, Hyderabad (Deccan).

Mr. A. Lakshminarayana Rao, District Board Engineer, Coddapah.

Mr. Pestonji L. Golwala, Civil Engineer, C/o Chief Engineer, Bombay. Port Trust, Ballard Estate, Fort, Bombay.

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Khan Bahadur J. R. Colabawala, State Engineer, Khairpur Mirs (Sind).

Mr. J. S. Narasimham, Roads Supervisor, Town Improvement Trust, Secunderabad.

Col. G. E. Sopwith, General Manager, Shalimar Tar Products, Ltd., Calcutta.

Mr. J. R. Jussawalla, State Engineer, Cambay.

Mr. V. H. Sadarangani, College of Engineering, Madras, Saidapet.

Mr. Syed Arifuddin, Superintending Engineer, Public Works Department, 4th Circle, Hyderabad (Deccan).

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Mr. S. V. Jagjivan, Sub-Divisional Officer, Khairpur Sub-Division, Khairpur Mirs (Sind).

Mr. B. R. Malhotra, Offg. Executive Engineer, Bilot Division, C/o Postmaster, Kundian, N.-W. F. Province.

Mr. S. M. Gupta, Assistant Engineer, Public Works Department, Pegu, Burma.

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Mr. B. Narasimha Shenoy, District Board Engineer, Chittoor.

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Mr. Hardit Singh, Assistant Engineer, Public Works Department, Mardan, N.-W. F. Province.

Lt.-Col. H. S. Northey, Superintending Engineer, Coimbatore.

Mr. Brij Mohan Lal, Executive Engineer, Gurgaon.

Rao Saheb V. G. Bhave, State Engineer, Sangli.

Mr. M. R. Patel, Executive Engineer, Navsari (Baroda State).

Mr. Madho Prasad Srivastava, District Board Engineer, Lucknow.

Mr. A. C. Mukerjee, Executive Engineer, Provincial Division, Agra.

Mr. G. Gopala Acharya, Assistant Engineer, Public Works Department, Lalgudy (Trichy. District).

Khan Bahadur M. Z. A. Faruqui, Executive Engineer, Central Public Works Department, New Delhi.

Mr. H. Ramaswamy, District Board Engineer, Dharwar (Bombay Presidency).

Mr. K. L. H. Wadley, Assistant Executive Engineer, Central Public Works Department, Simla.

Mr. Manohar Nath, Executive Officer, Municipal Board Meerut.

Mr. Majidullah Khan, Executive Engineer, Public Works Department, Bannu.

Mr. S. Bashiram, Superintending Engineer, II Circle, Ambala.

Mr. V. S. Srinivasa Raghava Acharyar, District Board Engineer, Cuddalore N. T. (South India).

Mr. Jagdish Prasad, District Engineer, Garhwal, Pauri (U. P.).

Mr. Bishamber Dyal, District Engineer, Rohtak.

Mr. C. R. Katkoia, State Engineer, Cutch State, Bhuj.

Mr. G. M. Mckelvie, Executive Engineer, Public Works Department, Akola (Berar).

Mr. G. Fairs, Sub-Divisional Officer, Public Works Department, Dera Ismail Khan.

Mr. Ishtiaq Ali, Assistant Municipal Engineer, Delhi.

Mr. A. Vipan, Chief Engineer, Government of Orissa, Public Works Department, Cuttack.

Mr. S. K. Ghose, Assistant Engineer, Patna Division, Patna.

Mr. T. R. Ramaswami Iyer, Ramnad District Board Engineer, Madura.

Mr. C. P. M. Harrison, Chief Engineer, Bengal Public Works Department, Calcutta.

Rai Bahadur S. N. Bhaduri, Chief Engineer, Gwalior Public Works Department, Gwalior.

Mr. V. P. Bedekar, State Engineer, Miraj (Senior) (Deccan State).

Mr. R. H. T. Mackenzie, Chief Engineer, Bikaner State, Bikaner.

Rai Bahadur A. P. Varma, Chief Engineer, Patiala State, Patiala.

Mr. B. D. Nanda, Divisional Engineer, Baramulla (Kashmir).

Mr. J. C. Sahney, District Board Engineer, Jhansi, U. P.

Mr. Jagmohanlal Bhatnagar, State Engineer, Jhalawar State, Jhalrapatan (Rajputana).

Mr. M. J. Shah, Road Engineer, Rajkot State, Rajkot Civil Station (Kathiawar).

Mr. Y. K. Ghanekar, Assistant Engineer, Kolhapur State, Kolhapur.

Mr. Lekh Raj. Civil Engineer, Kapurthala State, Kapurthala.

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THIRD

INDIAN ROADS CONGRESS, LUCKNOW, JANUARY 1937.

At their meeting held at Bangalore in January 1936, the Council of the Indian Roads Congress contemplated, on the invitation of the official representative from Bengal, holding the Third Indian Roads Congress at Calcutta in January 1937 when it was hoped that the proposed test track and road laboratory would be in working order at the Government Test House, Alipore, before January 1937. As this is not expected to be the case, the Council recently reconsidered the matter and decided to postpone the Calcutta session for 12 months (*i.e.*, till January 1938) and accepted the kind invitation of the Government of the United Provinces to hold the next session at Lucknow in January 1937. A detailed programme for the meeting will be notified shortly.

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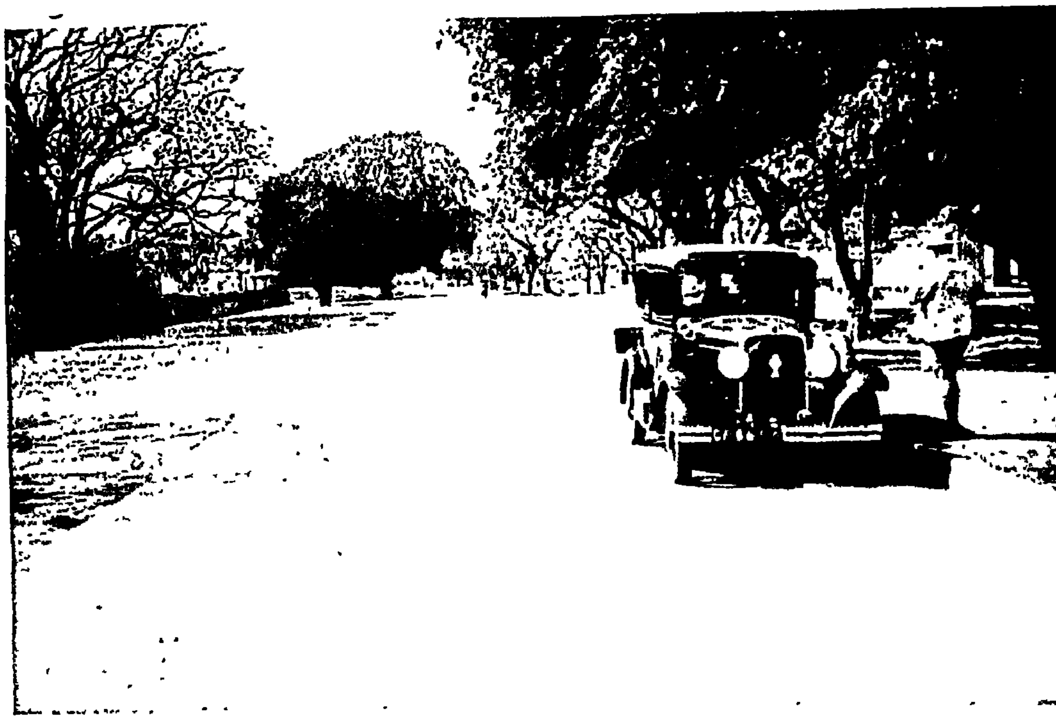

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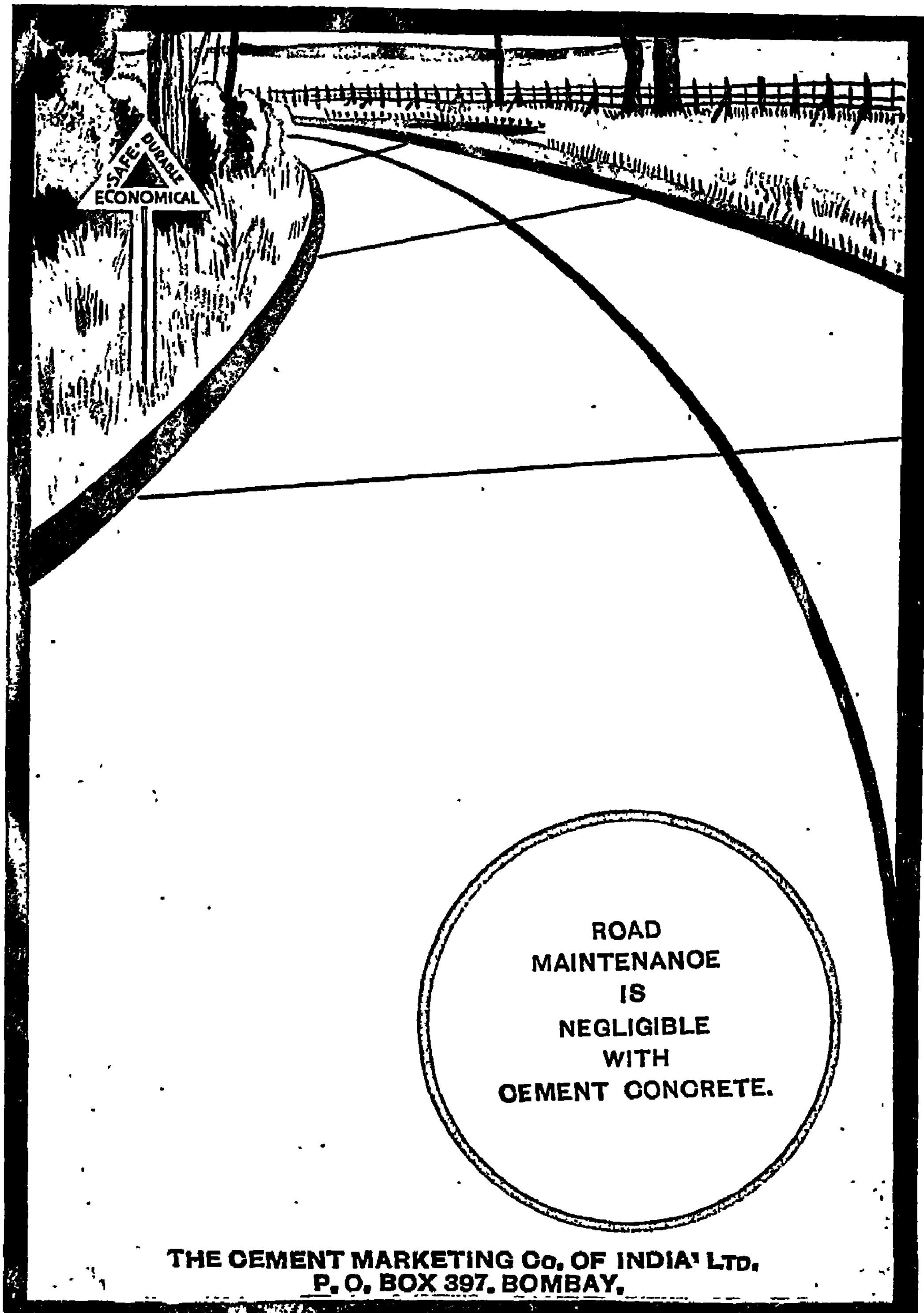
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Burn & Co., Ltd.	Rollers	vi
Cement Marketing Co. of India, Ltd.	Cement	xix—xxi
Dunlop Rubber Co. (India), Ltd.	Bullock Cart Equipment	iv
Firestone	Tyres	xvii—xviii
Gammon, Ltd., J. C.	Bridge Work	vii
General Motors, India, Ltd.	Motor Trucks	ii
Hindustan Construction Co., Ltd.	Road and Bridge Work	xiii
Hume Pipe Co., Ltd., The Indian	Hume Pipe Culverts	x
Jessop & Co., Ltd.	Bridge Work	Inside front cover i
John Fowler & Co. (India), Ltd.	Steam Rollers	xxiii
Marshall Sons & Co. (India), Ltd.	Diesel and Steam Rollers	xiv
Shalimar Tar Products (1935), Ltd.	Road Tar	v
Standard-Vacuum Oil Co.	Road Asphalts and Emulsions	xv
Texas Company (India), Ltd.	Paving Cement and Asphalt	xvi
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